Solano County Transit Intelligent
Transportation System Plan Final

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Solano County Transit Intelligent Transportation System Strategic Plan

Prepared for

Solano Links Transit Consortium

by

DKS Associates
TRANSPORTATION SOLUTIONS

DKS *Associates*

TRANSPORTATION SOLUTIONS

July 2, 2003

Mr. Kevin S. Daughton
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Fairfield Transportation Center
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Subject: **Solano County Transit Intelligent Transportation System Strategic Plan** P/A No. P01380-000

Dear Kevin:

DKS Associates is pleased to submit this final report on the Solano County Transit Intelligent Transportation System (ITS) Strategic Plan prepared for the SolanoLinks Transit Consortium. This Strategic Plan defines the ITS Vision and identifies strategies and initiatives over a 20-year period to improve the safety, efficiency and effectiveness of Solano County's transit system. These strategies and initiatives are intended to complement and enhance the County's Transit Plan with ITS technologies. The Implementation Plan provides a framework of ITS projects with appropriate timeframes such that the transit operators can choose which projects to move forward with and seek funding opportunities as the need arises.

It has been exciting to prepare this Strategic Plan for the SolanoLinks Transit Consortium. We thank you for the opportunity. Should you have any questions, please do not hesitate to call me or Elbert Chang.

Sincerely,

***DKS** Associates*
A California Corporation

Kevin G. Aguigui, P.E.
Project Manager

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1. INTRODUCTION

The Solano County Transit Intelligent Transportation Systems (ITS) Strategic Plan is part of a 20-year strategy to improve the safety and effectiveness of Solano County's transit system by complementing and enhancing the County Transit Plan with ITS technologies. It is a road map for the implementation of ITS strategies within Solano County.

The Solano County Transit ITS Strategic Plan is the process by which stakeholders envision the future of the County's transit system, and develop the necessary plans, procedures, policies, guidelines and operational strategies for deployment of ITS as one element of a broader transportation planning process.

This report presents The Solano County Transit ITS Strategic Plan and contains the following:

Chapter 1: Introduction – This chapter provides an introduction of the concept of Transit ITS, Transit ITS as it relates to Solano County, Transit ITS benefits, and the special Transit ITS needs in Solano County. It also describes the Solano Transit ITS Strategic Plan development process.

Chapter 2: Guiding Principles - This chapter discusses the overall program vision, the national ITS program goals and specific Solano County program goals. It also describes how the Solano County Transit ITS Plan program goals relate to the overall Solano County Comprehensive Transportation Plan goals and policies.

Chapter 3: State of Transit Systems in Solano County- This chapter assesses the existing transit systems as they relate to the application of Transit ITS. The results of the existing system inventory are summarized and presented in a series of maps displaying the transit infrastructure already in existence in Solano County.

Chapter 4: Needs Assessment - This chapter presents the specific needs of Solano County's transit operators.

Chapter 5: Concept of Operations - This chapter describes operational strategies for different sub-elements that are needed to accommodate the needs of the overall Solano Transit ITS Program, including the following: Automated Vehicle Location System (AVLS), Transit Priority Control System (TPCS), Dispatch Upgrades and Regional Communication System, and transit information field devices.

Chapter 6: System Architecture – This chapter describes how the various ITS components fit together within a County-wide System Architecture.

Chapter 7: Implementation Plan – This chapter presents how the Solano County Transit ITS Strategic Plan will be implemented, including implementation principles, an integrated action plan, and funding.

Background

Solano County serves as the gateway between the Central Valley and the San Francisco Bay Area. The population and employment of Solano County are expected to increase significantly through the year 2025, with only a few major new roadway capacity increases. A significant portion of the County's residents commute to employment outside the County.

In many areas of the United States, the approach to meeting the increasing demand for mobility has been to build more highways and bridges, and add more lanes to roads and streets. Over time, industry experts have come to realize we cannot instantly solve all of our transportation related problems through new transit services or expanded roads.

With the provision of additional transit capacity lagging behind demand, we must find alternative means to increase the efficiency of the existing transportation system. The deployment of ITS technologies provides this opportunity.

ITS, in brief, is a range of advanced transportation technologies that improves mobility and transit productivity, enhances safety, conserves energy resources, and reduces adverse environmental effects. Under ITS, the use of advanced technologies and management strategies compliment and enhance traditional transportation management. ITS is a proven and successful means of improving transit efficiency and safety. ITS is seen by the Federal government as the next major evolutionary stage of surface transportation, and is expected to be the focus of major metropolitan area implementation efforts early in this century, much as the completion of the national highway system was the focus of the last half of the 20th century.

What are Intelligent Transportation Systems (ITS)?[1]

A broad range of diverse technologies, known collectively as Intelligent Transportation Systems (ITS), ITS is comprised of a number of technologies, including information processing, communications, control, and electronics. The joining of these technologies with our transportation system will save lives, save time, and save money.

Among other services, ITS technologies:

[1] *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision*, January, 2002, prepared by the Intelligent Transportation Society of America in cooperation with the United States Department of Transportation

- Collect and transmit information on traffic conditions and transit schedules for travelers before and during their trips. When alerted to hazards and delays, travelers can change their plans to minimize inconvenience and additional strain on the system.

- Decrease congestion by reducing the number of traffic incidents, clearing them more quickly, rerouting traffic flow around them, and automatically collecting tolls.

- Improve the productivity of commercial, transit, and public safety fleets by using automated vehicle tracking and dispatch, and weigh-in-motion systems that speed vehicles through much of the red tape associated with interstate commerce.

- Assist drivers in reaching a desired destination with navigation systems enhanced with path finding, or route guidance.

These are just a few of the technologies being deployed. The complete list is lengthy, and is growing every day. The ITS industry in the United States is in its infancy.

Public agencies also stand to derive enormous benefits from the deployment of these technologies. For government agencies at all levels, the innovative application of advanced technologies means lower costs, enhanced services, and a healthier environment for the constituents these agencies serve.

Benefits of ITS

Transit Management Systems

Advanced Public Transportation Systems (APTS) include a number of applications that can help transit agencies increase the safety and operational efficiency of the nation's transit systems. Remote monitoring of transit vehicle status and passenger activity helps to provide additional safety and security to passengers. Transit ITS services also assist operators in maintaining vehicle fleets. Vehicle self diagnostics can alert mechanics of unexpected mechanical problems as well as routine maintenance needs. Automated vehicle location (AVL) and computer aided dispatch (CAD) can improve scheduling activities and schedule adherence.

Transit management systems have demonstrated that they are capable of reducing travel time both by improving the operation of the vehicles and the overall operation of the transportation network. Transit management systems improve schedule adherence and the dissemination of schedule and route information to passengers, resulting in a reduction in passenger wait time and improvement in transfer coordination. Also, APTS applications reduce the cost of system operations by improving staff productivity and the utilization of facilities and equipment.

For a summary of transit management systems deployment in 78 of the largest U.S. cities, refer to *www.itsdeployment.its.dot.gov*.

Combined CAD/AVL systems are some of the most widely deployed APTS applications. Analysis of these systems has begun to reveal their quantifiable impacts on schedule reliability. The unique conditions faced in each application of CAD/AVL and the different performance metrics used in evaluating them make summary assessments of the systems difficult. Results in the figure are from evaluations of implementations in Portland, Oregon, Kansas City, Missouri, and Baltimore, Maryland. Regardless of the performance measures used, many system evaluations indicate positive impacts on schedule reliability and operational efficiency. In addition to improvements in on-time performance, CAD/AVL systems allow agencies to gain the most from their vehicle resources, providing valuable information for operational control strategies that can reduce the number of vehicles necessary to provide the required level of service to transit passengers.

Passenger surveys reveal high levels of customer satisfaction with implemented APTS applications. Transit patrons appreciate the benefits of improved communication of transit route and schedule information through a variety of information dissemination technologies. The various surveillance technologies used in APTS also improve the safety and security of transit systems.

Existing Transit System Evaluations

Metro Online, a website providing route and schedule information for the Seattle area bus system, provides a valuable service to its users. Many users indicated in a survey that they had been long term users of this ITS service. Several recommended potential improvements to the site, including improvements to the route planning and transfer sections of the site.

Customer satisfaction was also high for Transit Watch, a system that provides actual arrival and departure information for passengers at key transit centers in Seattle. Transit riders indicated that they would like to see the information available at places where travel decisions are made. While the system did not increase the satisfaction of existing riders with the transit system as a whole, new riders were pleased with the system, which may indicate that it could help the bus network retain new transit patrons.

Since implementing an Automatic Vehicle Location (AVL) system, the Denver Regional Transportation District (RTD) has provided its transit customers with higher quality service. The RTD decreased the number of vehicles that arrived at stops early by 12% between 1992 and 1997. The number of late arriving-passengers decreased by 21%. Customer complaints decreased by 26% per 100,000 boardings, due in part to improved schedule adherence by RTD. Provision of a silent alarm feature with the AVL system has helped improve the safety of the transit system. Passenger assaults per 100,000 passengers decreased by 33% between 1992 and 1997.

The Outreach paratransit transportation broker in San Jose, California, realized significant benefits after implementing a digital geographic database, an Automatic Vehicle Location system on a portion of the vehicles under contract to Outreach, and an automatic scheduling and routing system. Outreach benefited from increased ridership, better on-time performance, and a $500,000 reduction in operating costs during the first year of operation. A study of the system revealed rides increased from 38% to 55%, and a reduction in the size of the paratransit fleet from 200 to 130 vehicles, and a reduction in the cost per passenger mile from $4.88 to $3.72.

Portland, Oregon's, Tri Met System achieved a 9.4% improvement in on-time performance after implementing an AVL and CAD systems. The variability in the headways between buses decreased by 5%, after implementation of the improvements. While no significant change was measured in the average run times for buses along the routes, with run times remaining about 1% longer than their scheduled values, the average coefficient of variability for bus run times did improve by 18%. No route experienced an increase in run time variability. These benefits, indicated by the comparison of before and after data, are consistent with the improved control available to transit supervisors after the implementation of the AVL and CAD systems. A modeling effort using the collected data to control for external impacts on bus run times determined the AVL/CAD system improved running times by 3.4%. Increases in the average number of stops made, the scheduled headways of buses, and the average departure delay of buses beginning their routes counteracted this improvement. This indicates that the AVL/CAD system allowed the Tri Met to accommodate these changing conditions without increasing bus run times.

A demonstration system in Valencia, Spain, incorporated a dynamic bus scheduling system and a remote maintenance monitoring system. This system led to efficiency gains including a 35% reduction in the time it takes to create a bus schedule and a 10% improvement in the cost effectiveness of schedules through reductions in waiting time. The maintenance system enabled a 20% to 30% reduction in the time required to detect and correct vehicle faults.

A European study investigating the use of Travel Dispatch Centers for coordinating and managing paratransit services demonstrated significant cost savings over previous implementations. Accounting for implementation costs, the system resulted in a 2% to 3% annual decrease in costs to provide paratransit service, which compares favorably with the previous experiences of a 15% annual increase.

A 1998 survey of transit riders in Ann Arbor, Michigan, assessed the impact of several transit safety and security enhancements, including on board video surveillance, emergency phones, video cameras at transit centers, enhanced lighting at transfer centers, and increased police presence. The surveillance systems were the safety enhancement most often noticed by respondents. The on board cameras were noticed by 70% of the respondents and the transit center cameras by 63%. Additional police presence was noticed by 51% of respondents, while the increased lighting was noticed by 42%. Only 28% of those responding to the survey noticed the emergency phones installed at transfer centers. Respondents rated all improvements very highly when asked the degree to which each improved their sense of security.

ITS and Solano County

In recent years, the various cities of Solano County have adopted various state-of-the-art electronic devices for improved transportation management. These devices, which will be discussed further in the inventory of existing systems, include:

- Emergency Vehicle Pre-emption (EVP) devices have been or are being installed at traffic signals in Vallejo, Fairfield and Suisun;
- Fairfield/Suisun Transit and Vallejo Transit buses are being equipped with emitters that notify traffic signals of their approach;
- A centralized signal control system, utilizing wireless spread-spectrum communications, is being implemented in Fairfield;
- A fiber-optic communications backbone for traffic signal controller communications has been implemented in Vallejo; and
- Traffic signal controllers are being upgraded in Fairfield that will allow for advanced communications and transportation flow management capabilities.

No amount of technology will eliminate traffic congestion, transit delays or safety concerns in Solano County. The demand for mobility will likely always exceed the capacity of the various facilities. However, Solano County Transit ITS system will help in the following ways:

- Provide real-time information (e.g., transit vehicle arrivals and departures), enabling the public to have an informed choice of travel time, mode and route, both before and during the journey. Information provided will include available transit routes, scheduled arrivals and departures, and real-time travel time estimates.
- Allow for late transit vehicles to request a transit priority from local traffic signals. Transit priority control will help to keep transit vehicles on schedule, make travel conditions more predictable, and improve safety.
- Provide automated visual and audible announcement of upcoming transit stops in conformance with 1990 Americans with Disabilities Act (ADA) guidelines. This will allow bus drivers to focus on passenger and vehicle safety.
- Collect demand and performance data that can be used in both real-time and off-line optimization as well as fine-tuning of the transportation systems' operation. Data can be analyzed automatically. This data includes travel time, dwell time, passenger on- and off counts per stop.
- Provide continuous and automatic exchanges of data with BART and 511® (and potentially other agencies) to coordinate and integrate the operations of different agencies' transit systems. This will enable control actions taken by the agencies to be compatible and synchronized, through automated data exchanges, enhanced

communications, and interactions between operations personnel. It will enable consolidated and consistent for travelers, and it will facilitate historical operational and performance data for all facilities to be consolidated and analyzed for overall transportation system evaluations and improvements.

- Reduce vehicle accidents by the introduction of proximity sensors around the transit vehicle that will allow the driver to "see" around the transit vehicle.
- Allow for electronic monitoring of transit vehicles for preventive and routine maintenance. The benefit of such monitoring being the reduction of maintenance costs.
- Translink and electronic fare collection will make it an easier, more pleasant experience for passengers.
- Provide tangible evidence of the activities and resources being applied to transit systems in the County, and assure the public that every modern tool is being applied to address the problem of traffic congestion. The visibility of the system to the public will assist in public relations.

Strategic Transit ITS Plan Development Process

In order to meet the National ITS Architecture guidelines, the resulting Solano County Transit ITS Plan has identified six key tasks:

- Inventory of Existing Systems;
- Needs Assessment;
- Concept of Operations;
- System Architecture;
- Outreach Program and Consensus Building; and
- Implementation Plan.

Figure 1.1 illustrates the process for the development of the Strategic Plan and how each task relates to each other.

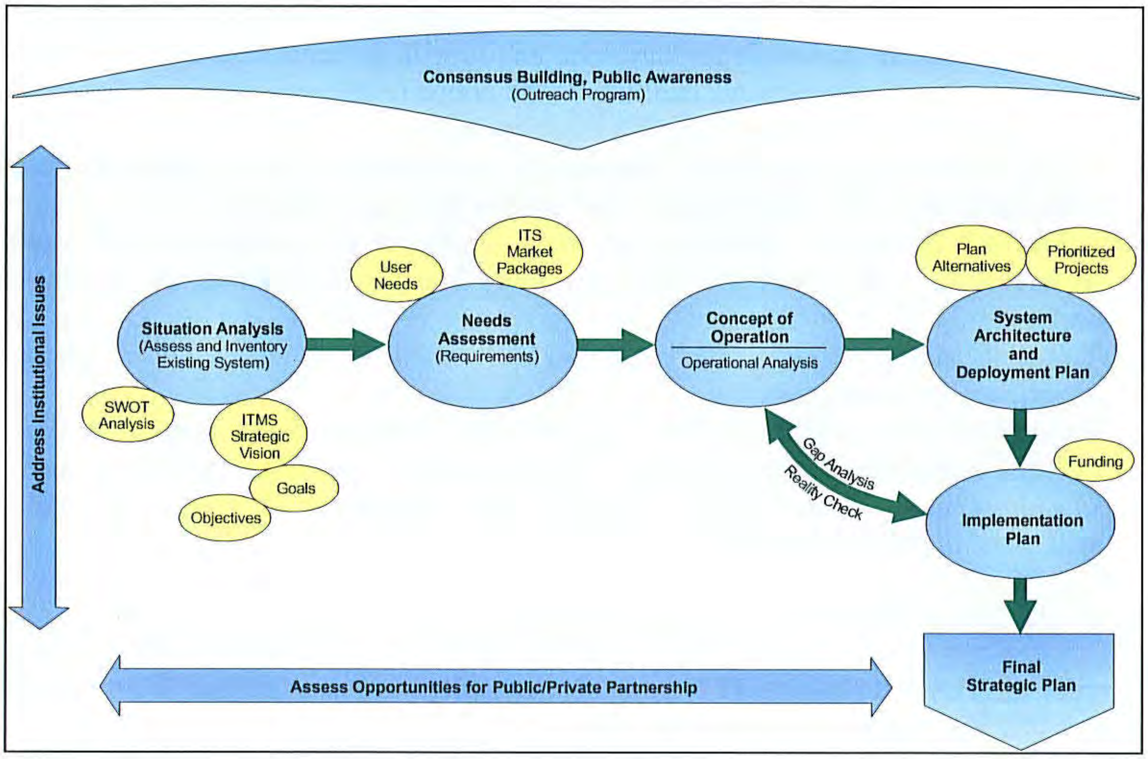


Figure 1-1: Solano Transit ITS Strategic Plan Development Process

This Plan was developed based on the involvement of key stakeholders. The key stakeholders interviewed were as follows:

- Fairfield/Suisun Transit
- Vallejo Transit
- Vacaville City Coach
- City of Fairfield
- City of Vacaville
- City of Vallejo
- City of Dixon
- Vallejo Transit-RunAbout
- City of Rio Vista/Rio Vista Transit
- City of Benicia/Benicia Transit

In addition, two workshops were held to present the concept of AVLS/TPCS of the Solano County Transit ITS Plan and to further identify specific needs. The following agencies attended these workshops:

- Solano County Transportation Authority
- City of Fairfield
- City of Vacaville

- City of Vallejo
- Vallejo Transit
- Fairfield/Suisun Transit
- Vacaville City Coach

Public Awareness Program

In order to improve public awareness of the Solano County Transit ITS Strategic Plan, a public awareness program should be implemented. This will stimulate public debate and build consensus. Effective education and communication about the purpose and need must occur in a targeted way before any actual construction begins.

The overall goals for the public awareness program are:

- Educate the public about ITS, the Solano County Transit ITS Strategic Plans and its facets, benefits, and ultimately the projects to be performed.
- Foster communication among various city, transit operators, Solano County Transportation Authority, and other regional transportation agencies to build partnerships and share resources.
- Canvass stakeholders such as the business community and the general public for suggestions in solving transportation problems.
- Gain political, financial and public support for the program.
- Serve as a focal point for proactive information and questions about the program for the Media.

Other outreach activities should include:

- Targeted outreach to local groups.
- Policymaker briefings to maintain clear and timely communications with elected and appointed officials and key agency representatives to ensure coordination with related efforts and to assist in preparing for, and responding to program developments and funding concerns.
- Media relations including press conferences and editorial boards.
- Develop collateral materials which may include newsletters, general information brochures, promotional materials, etc.

Overall, the Public Awareness Program for the Solano County Transit TIS Strategic Plan should provide information to, and sought input from, representatives of as many public and private stakeholders as was feasible.

2. GUIDING PRINCIPLES

The Solano County Transit Intelligent Transportation System (ITS) Plan was prepared based on the following guiding principles:

- The Solano County Transit ITS Plan must meet all of the objectives of the local agencies transportation plans in the County.

- The Solano County Transit ITS Plan must be based on consensus of key stakeholders. The overriding responsibility of the local and regional agencies within the County is to look out for the public good, to ensure that the future transportation system serves the widest possible constituency effectively and safely, to minimize the impact on the environment and to foster a robust and productive transportation system.

- The Solano County Transit ITS Plan must adhere to the Federal, State, and MPO (Metropolitan Planning Organization) guidelines and standards. This means conforming to standards developed under the National Transportation Communications for ITS Protocol (NTCIP) and several other guidelines by Federal Highway Administration (FHWA), Caltrans, and the Metropolitan Transportation Commission (MTC);

- The Solano County Transit ITS Plan must meet the challenges of interagency coordination. The institutional relationships move across the spectrum of communication, cooperation, coordination, and consolidation. Therefore, the Solano County Transit ITS Plan will make the increased level of inter-departmental and inter-jurisdictional coordination and communication possible; such higher levels of coordination are essential to capitalize on many of the promises of coordination; and

- By preparing a Transit ITS Plan, the Cities in Solano County are recognizing the importance of transit ITS in their respective city into the foreseeable future. This document will assure that the County not only gets funding for the most important projects, but also that each City within the County develops and implements the transit ITS projects at the appropriate time.

Solano County Transit ITS Plan Vision

The Solano County Transit ITS Plan vision was prepared as a guide for the cities within the County to see the future of transit ITS applications from their current position. It provides overall direction and expresses themes that the Strategic Plan should consider as it is implemented. Specific goals, objectives and missions that provide more specific direction to support the vision statement were developed. Collectively, these guide the planning and management of transit ITS applications within Solano County over the next

20 years. The following represents the Solano County Transit ITS Plan Vision Statement:

> The vision of the Solano County Transit ITS Plan is to implement a real-time advanced transit system across a common platform for the transit operators. The Transit ITS Plan will elevate the County's transit system into a better managed, well integrated, and universally available system that enables the movement of people and goods, and meets the challenges of the future. The system will provide a seamless and efficient transportation network for transit riders within the County.

The Solano County Transit ITS Plan Vision Statement contains two words that are underscored, and are particularly important to the overall program strategy: "integrated" and "efficient". "Integrated," in this case, means a transformation from today's independent system, to broadening the thinking beyond individual agencies. It means being a catalyst for promoting greater consideration of system-wide operations and management as a part of the overall approach to meeting the future needs of the County's transit system. The potential of ITS applications will be considered part of a more cohesive set of initiatives and projects that may involve both traditional and technological improvements in an integrated fashion. "Efficiency" means maximizing the usage of current infrastructure by providing the highest level of operability. This will result in better return on investment.

This vision needs to be reflected in a variety of plans, programs, and projects at both institutional and physical levels. The strategic plan is a reflection of that vision, and is a living document that needs to be referred to and updated on a regular basis.

It also should be noted that the Solano County Transit ITS Plan is influenced by many other planning, design and construction activities. These include the Solano County Transportation Authority's Transit Plan, the California Transportation Plan, Caltrans District 4 Capital Improvement Programs, MTC's Transportation Plan, Regional and Federal Transportation Improvement Programs (RTIPs or TIPs), MTC's TravInfo Program, the Solano County Comprehensive Transportation Plan, each City's Capital Improvement Program within the County, the Bike Plans adopted by the cities within Solano County, and other Transportation Authorities plans and programs. To assure that Solano County Transit ITS applications are consistent with plans and policies adopted by each of these activities the following Solano County Transit ITS Plan Mission was developed.

Solano County Transit ITS Plan Mission

The mission of Solano County Transit ITS Strategic Plan is to:

- Enhance the transit system's productivity, mobility, efficiency and safety;
- Build transit ITS communication network infrastructure and upgrade field devices;

- Promote economic prosperity and livability through the use of transit ITS technologies;
- Integrate with the future transit projects within the County;
- Streamline ITS in each city's transit planning process within the County;
- Streamline and incorporate transit ITS into future construction projects of various cities; and
- Integrate with all regional transit ITS activities.

National ITS Program[1]

In January 2002, the Intelligent Transportation Society of America (ITSA), in cooperation with the United States Department of Transportation, issued an updated National Intelligent Transportation Systems Program Plan: A Ten-Year Vision. This document explains the current status, opportunities, benefits, challenges and actions related to the programmatic and enabling themes. The following National ITS Program Vision is taken directly from this document.

Vision

The ITS vision is to ensure that:

- Future transportation systems will be managed and operated to provide seamless, end-to-end intermodal passenger travel regardless of traveler age, disability, or location and efficient, seamless, end-to-end intermodal freight movement;

- Public policy and private sector decision makers will seize the opportunity to make ITS a vital driver in achieving the vision of the transportation system for the 21st century; and

- Future transportation systems will be secure, customer-oriented, performance-driven, responsive in times of crisis and institutionally innovative, enabled by information from a fully integrated spectrum of computing, communications and sensor technologies.

The introduction of ITS technologies into the institutional and funding framework of surface transportation, the current and proposed transportation infrastructure and future vehicle development offers the opportunity to achieve:

- An electronic information infrastructure that works in concert with the physical infrastructure to maximize the efficiency and utility of the system and encourage modal integration and consumer choice;

- A secure system that can both detect and respond to regional crises;

[1] The National ITS Program Vision and Goals were taken from *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision*, Intelligent Transportation Society of America. January 2002.

- Far fewer and less severe crashes for all types of vehicles and faster response times when crashes do occur;

- Information for operators and users of the transportation system to help contain congestion and increase the effective capacity of the system while reducing the need for new construction;

- Facilities, technology and information that help reduce energy consumption and negative environmental impact; and

- A vital domestic ITS industry that is able to compete effectively at home and in the international marketplace.

Goals

The Intelligent Transportation Society of America (ITSA), in cooperation with the United States Department of Transportation (DOT) also explained in this document the current status, opportunities, benefits, challenges and actions related to the programmatic and enabling themes. The following National ITS Program Goals is taken directly from this document.
This Plan identifies five benefit areas and associated goals against which change and progress can be measured. These goals provide the guideposts for fully realizing the opportunities that ITS technology can provide in enhancing the operation of the nation's transportation systems, in improving the quality of life for all citizens and in increasing user satisfaction, whether for business or personal travel.

<u>Safety.</u> ITS presents the opportunity to save thousands of lives and billions of dollars in property and prevent millions of injuries and untold productivity losses through improvements such as:

- Preventing crashes in large numbers through technology that improves the performance of drivers, vehicles and the infrastructure;

- Reducing the severity of crashes that do occur and mitigating their consequences through improved, sensor-based injury-reducing technology in vehicles and by enabling surer and swifter responses by emergency services;

- Identifying and influencing the behavior of high-risk commercial drivers; identifying high-risk carriers and working with them to improve their safety management processes;

- Encouraging safe and responsible behavior through automated enforcement;

- Enabling communication and cooperation between vehicles and the infrastructure, to allow vehicle performance to adapt to changing traffic patterns, weather conditions and topographic features;

- Connecting vehicles, vehicle operators, travelers, public safety agencies and the infrastructure through an integrated network of transportation and environmental information and applying information to enhance safety management by both the public and private sectors; and

- Helping to keep transportation safe from terrorist attacks.

An effective safety program of pre-competitive cooperative research and deployment leadership will help to put American industry at the forefront of these lifesaving technologies, assuring that domestic requirements are thoroughly met and bringing the benefits of these technologies promptly to the American people. The goal is to reduce annual transportation-related fatalities by 15% overall by 2011, saving 5,000-7,000 lives per year.

<u>Security.</u> ITS provides tools and enhanced opportunities to help safeguard the transportation system against a variety of threats, both natural and manmade and to react swiftly and responsively in case of disruptions, by:

- Providing commercial vehicle operations surveillance, matching cargo against bills of lading, matching routing against intended destination and providing commercial operator verification;

- Providing surveillance and analysis technology for public transit, including passengers, operators and route/schedule adherence;

- Providing surveillance and detection at major transportation centers;

- Providing tools for infrastructure surveillance and the intelligent computer-assisted analysis of raw surveillance data to detect and prevent potential threats;

- Providing software safeguards against inadvertent or deliberate incursions into transportation systems and their information networks;

- Helping infrastructure managers track the performance of the system, including identifying and assessing breakdowns from whatever cause;

- Providing the logistical and communications tools to enhance existing systems to enable swift and appropriate responses to system disruptions, rescue the injured, clear guideways, smoothly reroute travel to available alternatives and restore services as promptly as possible;

- Helping to coordinate transportation agency support of law enforcement, defense, emergency response and security organizations;

- Helping to assure that vehicle and drivers' licenses, particularly commercial licenses, are issued appropriately; and

- Providing the public with prompt and accurate information on transportation alternatives in case of disruptions to portions of the system or when quarantine or evacuation is necessary.

The goal is a transportation system that is well-protected against attacks and responds effectively to natural and manmade threats and disasters, enabling the continued movement of people and goods even in times of crisis.

Efficiency/Economy. ITS provides the means to save large amounts of time and money by more effectively and economically moving people and goods throughout the transportation system. Beyond reducing the delays and the property and healthcare costs related to collisions, ITS will provide infrastructure management tools and information for both operators and users of the transportation system that will enhance efficiency and economy by making improvements such as:

- Delivering faster, more accurate and comprehensive travel information via the media to more users to enable decision making on whether to make a trip, when to start, and which mode(s) of transportation to use;

- Providing information management tools to better manage the infrastructure, increasing its effective capacity and throughput;

- Providing information management tools to facilitate the effective use of new construction techniques and materials, as well as to monitor the condition of guideways, bridges, stations, terminals, tunnels and pedestrian cross-walks to economically guide maintenance and repair of the infrastructure, prolong its life and moderate the need for its expansion and replacement;

- Tracking and providing information about shipments, containers, trucks, trains and freight cars through checkpoints and between terminals, shipping and arrival points, thereby enabling more reliable and timely freight movement and management;

- Reducing administrative and regulatory costs for public agencies and commercial vehicle operators; and

- Promoting automated infrastructure-vehicle cooperation to optimize both individual trips and overall system throughput.

The goal is to save at least $20 billion per year by enhancing throughput and capacity through better information, better system management, as well as the containment of congestion by providing for the efficient end-to-end movement of people and goods, including quick, seamless intermodal transitions.

Mobility/Access. ITS provides travel opportunities and additional travel choices over more modes for more users – wherever they live, work and play – regardless of age or disability, by:

- Providing better, faster information for both users and operators of the transportation system, which opens new employment and recreation opportunities and also helps make travel time more productive by providing reliable information about traffic conditions along their routes;
- Providing necessary information in times of regional crisis – natural or manmade – to maintain mobility;
- Providing information on available services to the public to help make public transportation more innovative and flexible, offering more and better travel services to the elderly, the disabled and non-drivers in both urban and rural settings; and
- Helping to inform infrastructure managers of customer wants and needs.

The goal is universally available information that supports seamless, end-to-end travel choices for all users of the transportation system.

Energy/Environment. ITS helps the environment and conserves energy by optimizing trips, eliminating unnecessary travel miles and reducing time spent caught in traffic through improvements such as:

- Keeping traffic flowing – on urban freeways, on toll roads, at commercial vehicle checkpoints and elsewhere – thereby increasing effective capacity, reducing delays due to congestion and incidents and reducing the pollution caused by stop-and-go driving;
- Using location-based road conditions and weather information to help make vehicles more operationally efficient;
- Making trips more efficient through more optimal route planning and timing to direct the driver around congested areas in the least amount of travel time possible;
- Enabling flexible transportation pricing and demand management to respond to the current state of congestion and pollution;

- Increasing the attractiveness of the use of public transportation and ride sharing, which are our most energy-efficient and environmentally-friendly travel modes;

- Strengthening compliance with vehicle emissions standards for all vehicles.

In addition, as part of an overall system approach to vehicle design, ITS contributes to improved fuel consumption by enabling more efficient vehicle performance, and by allowing vehicle weight to be reduced without compromising the safety of occupants. Altogether, ITS helps to contain fuel consumption and noxious emissions, reduce dependence on foreign energy supplies and safeguard the quality of the air. The goal is to save a minimum of one billion gallons of gasoline each year, and to reduce emissions at least in proportion to this fuel saving[2].

Solano County Transit ITS Plan Goals

Transportation Management

The goal of the Solano County Transit ITS Plan is to build an integrated network of transit ITS infrastructure and create a balanced, multi-modal transportation system that is well-managed and intelligently controlled, enabling the continued efficient movement of people in Solano County.

The Plan strives to attain this goal by:

- Mainstreaming the key elements of the program into the local agencies within the County future transportation planning process;

- Integrating with all transportation service providers within the County;

- Integrating with other regional ITS plans;

- Early detection of traffic incidents on I-80 and the local streets, and the ability to control traffic flow in response to such incidents by means of traffic signals, electronic signs and real-time information system; and

- Continuous monitoring, control, and logging of selected transportation and environmental conditions.

Transit System Efficiency

[2] According to the TTI 2001 Mobility Study, congestion in the 68 largest urban areas of the U.S. results in the annual waste of 6.8 billion gallons of gasoline. If ITS can mitigate 15% of this waste in ten years, an achievable goal, it will save 1.02 billion gallons of gasoline per year.

The goal of Solano County Transit ITS Plan is to assure an efficient transit system and utilize ITS technologies to encourage Solano County residents and visitors to use transit. The Solano County Transit ITS Plan will enhance and complement the Solano County Transit Plan and restore balance to the County's Transportation System.

The Plan strives to attain these goals by:

- Establishing an integration mechanism with the transit agencies and Solano Transportation Authority (STA);
- Assuring transit schedule adherence and improved on-time performance;
- Securing funding for transit projects within Solano County;
- Facilitating the use of public transit as the first choice of transportation by travelers; and
- Allowing transit vehicles to request signal preemption to adhere and meet their on time performance and schedule.

Information

The goal of the Solano County Transit ITS Plan is to provide universally available information on different travel modes and choices that are integrated with Bay Area's 511® transportation information system.

The Plan strives to attain this goal by:

- Providing real-time bus arrival information at all bus stations;
- Providing real-time transportation information at key intermodal points and major activity centers through kiosks and electronic information signs;
- Providing transportation information directly to Bay Area TravInfo for trip planning and regional mobility;
- Providing traffic conditions information to media, cable TV and other service providers;
- Allowing travelers to access the various websites within the County for video images of traffic conditions and other transportation information, including, but not limited to, transit information, BART schedules, taxi and limo services, ports and airports information;
- Providing personalized traveler information through service providers; and

- Providing motorists with real-time information through electronic message signs, informing motorists about congestion on I-80 and the local streets, traffic conditions on the Carquinez and Benicia Bridge, and assisting motorists traveling toward major events about which exits would be their best choice, and about the locations of nearby parking lots with available spaces.

3. CURRENT STATE OF THE TRANSIT SYSTEM

The following information is taken from the Transit Element of the Solano Comprehensive Transportation Plan[1].

The objective of this chapter is to lay the groundwork for future chapters by explaining the current state of Solano County in terms of existing transit systems and future needs. The first section describes transit conditions in Solano County; the second section will define each of the currently used in Solano County.

Transit System

The intercity transit elements of the Solano County Comprehensive Transportation Plan consist of five components:

- Intercity Bus
- Intercity Passenger Rail
- Ferry Services
- Support Systems

Each of these components is described below.

Intercity Bus Services

Intercity transit services serving Solano County are provided and supported by the following key agencies:

- Solano Transportation Authority (STA) and its Solano/Napa Commuter Information (SNCI) program;
- Vallejo Transit (VT);
- Fairfield-Suisun Transit (FST);
- Benicia Transit (BT);
- Vacaville City Coach (VCC);
- Dixon Readi Ride;
- Rio Vista Paratransit;
- Solano County;
- Metropolitan Transportation Commission (MTC); and
- Caltrans.

In addition to these key agencies, two neighboring counties provide important intercity connections to Solano County. VINE Transit and YoloBus provide linkages to Napa and to Winters/Davis, respectively.

[1] Prepared for the Solano Transportation Authority.

No intercity public transit services are presently provided across Highway 37 linking Vallejo and Solano County to Marin and Sonoma counties other than the dedicated Capitol Corridor/Amtrak feeder buses. Similarly, no direct public transit bus services are provided to Sacramento from Solano County.

Vallejo Transit, Fairfield-Suisun Transit, Benicia Transit, Vacaville City Coach and Dixon Readi-Ride provide local feeder bus services in support of intercity transit services. The STA's Solano/Napa Commuter Information (SNCI) program and Caltrans are key partners with park-and-ride facilities.

In addition to Solano County, the SNCI program also serves Napa County. Rio Vista provides some intercity specialty transport services. All the agencies are important partners in funding public transit services in Solano County. The Solano Transportation Authority is the central point for coordinating funding, marketing, and other major elements important to intercity bus services.

San Joaquin County's transit operator operates one daily roundtrip between Stockton and Napa, which passes through Solano County without making any passenger stops.
In this section are descriptions of current bus services. Figure 3.1 shows an overview of the bus transit service throughout Solano County.

Existing Bus Services

Overall, the SolanoLinks bus services, the Capitol Corridor passenger rail service, and the Baylink Ferry serves approximately 6,000 daily passenger trips on an average weekday. Capitol Corridor service carries about 300 daily riders from Solano's only rail station, located in Suisun City. The Baylink ferry service carries about 2,800 daily riders. Vallejo Transit serves about 2,300 trips to and from the County on Routes 80, 90 and 91. Fairfield-Suisun Transit carries about 150 trips to and from the County on Routes 30 and 40 and Benicia Transit is estimated to carry 400 daily riders to/from Solano County on an average weekday. As such, the Capitol Corridor serves approximately 5 percent of intercity transit trips to points outside Solano County, and the Baylink ferry serves about 45 percent with the remaining 50 percent served by intercity bus services.

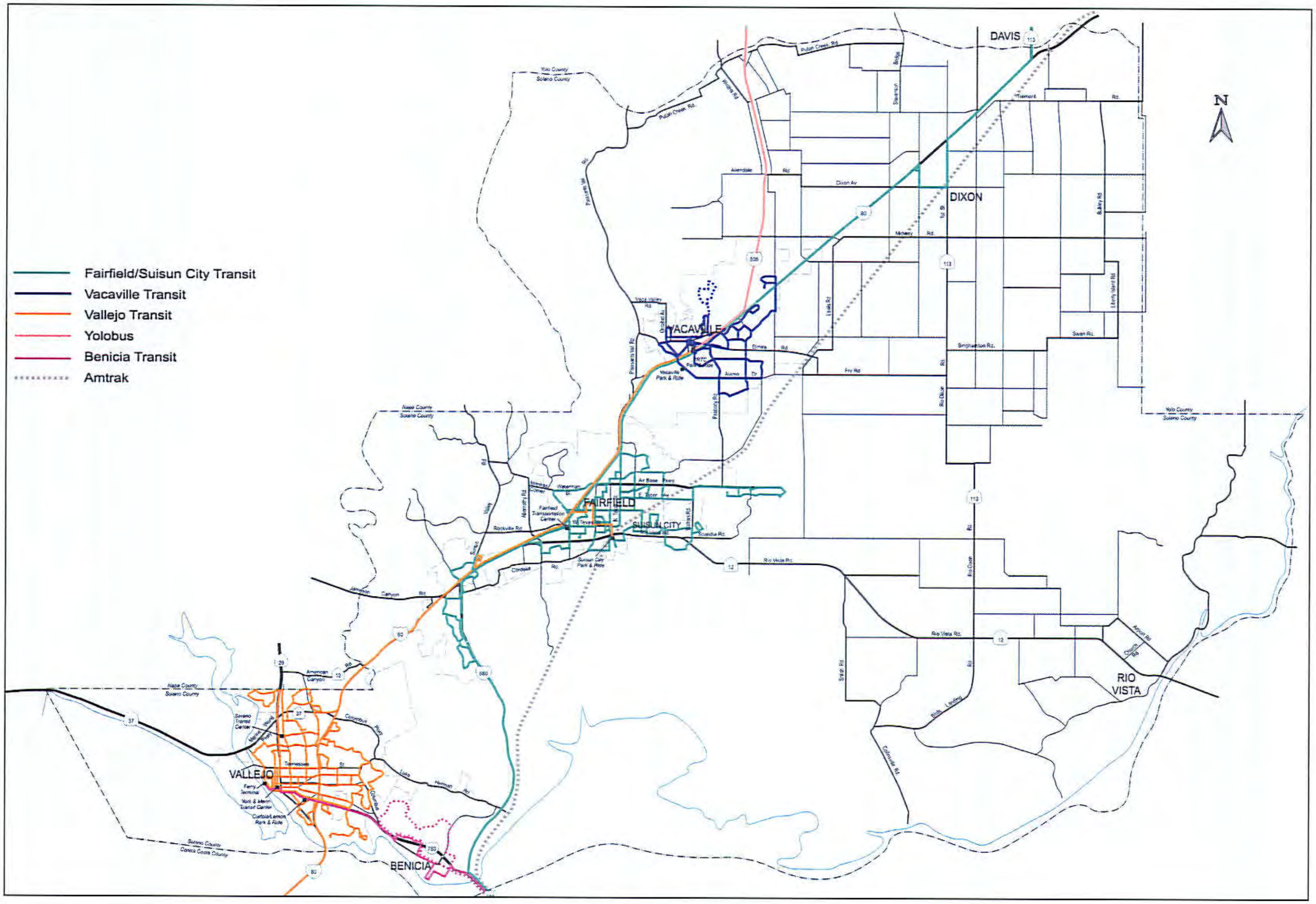


Figure 3-1- Existing Transit Routes

Vallejo Transit Bus Service

Vallejo Transit operates four regional bus services. Two other bus routes, the 92 and 100 were recently discontinued due in large part to capacity constraints on the Baylink ferry service. The four current regional bus lines operated by Vallejo Transit are:

- Route 80 Vallejo to El Cerrito del Norte BART
- Route 85 Fairfield and Suisun City to Vallejo via Solano College
- Route 90 Fairfield and Suisun City to El Cerrito del Norte BART
- Route 91 Vacaville to El Cerrito del Norte BART

Equipment and Support Facilities. Vallejo Transit operates from an extensive and modern maintenance facility located in north Vallejo. This city-owned five-acre facility currently can accommodate 63 buses, although it was originally designed for 48 vehicles.

A total of 16 vehicles are assigned to these intercity services (nine on Route 80, two on Route 85, and five on Routes 90/91). All vehicles are standard transit coaches (generally buses with utilitarian seats, hard floors, standing room, and several doors), as opposed to more comfortable over-the-road coaches (generally intercity-like buses which have larger, more comfortable seats, less standing room, and a quieter ride), which are used by Golden Gate Transit, and recently by AC Transit, for long-haul express bus services. Buses for express routes 85, 90 and 91 enter and leave service each day from Fairfield and Vacaville terminals. The distance between the Vallejo Transit bus storage yard and the Routes 85 and 90 service portal is approximately 16 miles. The distance between Route 91's service portal and the Vallejo Transit storage yard is about 24 miles. At average speeds of 55 mph it requires 18 minutes each day to put a bus into service for Routes 85 and 91, and 25 minutes each day to put a bus into service for Route 90. These are unproductive hours during which no passengers are served.

Passenger facilities are generally good, with on-going planning for additional improvements. At the El Cerrito del Norte BART Station, buses use the improved bus waiting areas. There is good signage and adequate passenger shelter. The Curtola park-and-ride facility's 450 auto spaces are often full by 7 am. The City of Vallejo is in the process of developing a major improvement to the ferry terminal. This Vallejo Station project would provide 1,400 parking spaces and enhanced bus transfer facilities.

Fairfield-Suisun Transit

FST operates three intercity routes: Route 20 links Fairfield and Vacaville, Route 30 links Fairfield, Vacaville, Dixon and UC Davis, and Route 40 links Vacaville, Fairfield and the Pleasant Hill BART station. Service frequencies on all three lines are sparse. Service is fully linked at various locations in northern Solano County. A major new facility, the Fairfield Transportation Center, opened last year. Other key transfer nodes include the Vacaville Regional Transportation Center, Solano Mall, and the Suisun City Amtrak Station. FST intercity routes serve the Pleasant Hill BART station, which allow easy connections to BART for trips to Oakland and San Francisco. The public timetable includes the connecting times (which are generally less than 10 minutes) and the overall trip times from Fairfield and Vacaville to San Francisco (about 90 minutes).

Equipment and Support Facilities. The City of Fairfield owns 26 transit vehicles, and uses 19 of these vehicles in both intercity and local service. The vehicles are stored at the city's corporation yard, with city staff servicing and maintaining the vehicles.

Of the 26 buses, five are assigned to Routes 20, 30 and 40, of which three are assigned to Route 40. Buses for both Routes 20 and 40 enter and exit service at Vacaville. Route 30 enters and exits service from Fairfield. The distance between Fairfield-Suisun Transit's bus storage yard and the Vacaville service portal is about eight miles, and involves approximately 30 minutes (15 minutes each way) daily per bus to get buses into and out of service each day.

The city is aggressively emphasizing park-and-ride facilities, including the Fairfield Transportation Center, which combines a 400-space park-and ride garage with a large bus transfer area.

Benicia Transit

Benicia Transit operates two intercity bus routes. Both routes provide connections to the Pleasant Hill BART Station. The main route also connects to the Vallejo Ferry Terminal and downtown Vallejo's Transit Center. The main intercity bus service operates from Vallejo Transit's York and Marin Transit Center to the Pleasant Hill BART Station via the Curtola Park-and-ride lot, Military West & 14th, Solano Square, H and E 3rd Streets L and E. 5th Streets, and Sun Valley Mall.

Benicia Transit operates another Pleasant Hill BART commute route from North Hills and Southampton. Two morning trips and three afternoon trips are provided in the commute direction of travel (Solano to Contra Costa). The route originates in Benicia at Columbus Parkway and Rose Drive, passes Rose Drive and Oxford Way, Rose Drive and Hastings, Hastings and Southampton, Turner and Larkin, Larkin and Panorama, Panorama and Chelsea Hills, and Chelsea Hills and Southampton before getting on I-780 to BART. Buses run empty in the off-peak direction of travel (deadhead) in order to quickly get into position for another peak direction trip.

Equipment and Support Facilities. The City owns a fleet of transit vehicles, which are stored and maintained at contractor facilities. Vehicles are fueled at the City Corporation yard. The peak direction of morning travel is towards Pleasant Hill BART and away from it in the evening. This suggests that the most efficient location to introduce and remove buses from service would be in Vallejo.

YoloBus

YoloBus operates one bus (Route 220) from Davis via Winters to Vacaville. It makes three roundtrips daily to Vacaville.

Summary

Nine public intercity bus routes are operated by Solano County agencies. One route connects to Davis, three routes connect to the Pleasant Hill BART Station, one route connects to the Vallejo Ferry Terminal and three routes connect to the del Norte BART Station. Public intercity bus connections to Napa from Vallejo are provided by VINE Transit, and YoloBus provides connections to Winters and Davis from Vacaville. No direct public intercity transit service presently exists to Sacramento from Solano County. Service is very sparse along the I-80 Corridor east of Vacaville, consisting only of Route 30. The segment between Vacaville and Fairfield is served by four routes (FTS routes 20, 30 and 40; and Vallejo Transit route 91). The segment between Vallejo and del Norte BART Station is served by 27 bus trips in each direction on an average weekday. There is no service to Sacramento.

Rail Service

Passenger rail services and their supporting network of feeder bus services link Solano County to the Bay Area and to the Sacramento Region.

<u>Equipment and Support Facilities</u>. The Suisun City station is the historic Southern Pacific depot serving both Suisun and Fairfield. The building was renovated, new passenger platforms were installed, and parking and bus loading space was improved. It has both a station-side platform and a center passenger loading platform. The Suisun City Redevelopment Agency is responsible for station maintenance and operating costs. Efforts are underway to add a third rail track for freight use, and to add parking at the present lot and also across the tracks on the north side. No decision has been made regarding the relocation of the center platform to a side platform serving the westbound track. As train frequencies increase, the likelihood of westbound and eastbound trains arriving at the same time will also increase.

Ferry Service

Existing Ferry Service (Vallejo Baylink)

Successful expansion of ferry service with borrowed vessels after the 1989 Loma Prieta earthquake led to the 1991 Vallejo Ferry Plan, which was the impetus for the current Vallejo Baylink ferry and bus network. As a result of the adoption of the Ferry Plan, the City acquired federal, state and regional funds to move forward with implementation. The first step was the 1994 City acquisition of the M.V. Jet Cat Express, a 28-knot, 365-

passenger vessel. The City selected Blue and Gold Fleet of San Francisco to operate the ferry service under contract.

Baylink ferries operate over a 24 nautical-mile route between the Vallejo Ferry Terminal and the San Francisco Ferry Building. Several trips a day also stop at Fisherman's Wharf and Pier 41. One morning trip is provided daily from Vallejo to Angel Island State Park, with a return in the late afternoon. The running time for the basic Vallejo to San Francisco route is 53-55 minutes. The Jet Cat Express, the older back-up and weekend vessel, takes five to ten minutes longer.

The ferries operate from 6:00 a.m. to 8:30 p.m. on weekdays, with trips approximately once an hour during peak periods, and every second hour off-peak. Ferries provide eleven round trips daily, with five additional trips provided by bus.

On weekends and holidays, six round trips are scheduled in winter, and eleven during the spring, summer and early fall periods. Weekend schedules operate from 8:00 a.m. to 8:30 p.m. year round. Because demand exceeded vessel capacity, Vallejo initiated a supplemental Baylink bus service (Route 200) in June 1998, initially intended for the afternoon peak period, but presently including two morning (when needed) and four afternoon supplemental bus trips. Two additional return bus trips were added at 7:30 p.m. and 10:30 p.m. to provide schedule flexibility for Baylink patrons.

<u>Facilities and Equipment</u>. The 10,000 square-foot Vallejo ferry terminal building was completed in 1988, and includes a waiting room, ticket office, restroom facilities, and concession areas. It was funded by a combination of local redevelopment and state funding. The terminal also has a high-capacity dock, which allows rapid boarding and disembarking from both vessel doors.

The primary vessels used for the Vallejo Baylink ferry service are two 35-knot, 300-passenger catamaran ferries and a back-up vessel with a capacity of 300 passengers and a 32 knot speed. Vallejo currently uses an interim vessel maintenance facility at Mare Island. There is leased berthing space with spare parts, a small shop, and operational offices approximately one mile north of the ferry terminal.

Vallejo has selected Mare Island Building 165 as the permanent home of the Baylink ferry maintenance facility. This will allow for on-going maintenance needs of the expanding vessel fleet. At completion, the project will include an upgraded maintenance dock and overnight docking facilities, fuel storage sufficient for a week of operations, maintenance and operations offices, workshops and parts storage.

The Port of San Francisco has implemented Phase 1 of Ferry Building terminal improvements, which upgraded the dock presently in use for most trips to San Francisco. Vallejo is completing the permit process for a new public dock at San Francisco Pier 43, Fisherman's Wharf, which will be available for all ferry services.

In 1999, Vallejo paved and lit the 700-space interim parking lot across Mare Island Way from the Vallejo Ferry Terminal. Capacity continues to be added to accommodate demand.

Intercity Transit Support Systems

This section describes current intercity transit support systems, which include park and ride facilities, intermodal bus transit-oriented centers, and intermodal ferry and rail centers. Figure 2.2 shows an overview of these support systems throughout Solano County.

Park and Ride Facilities

There are ten formal park-and-ride locations in Solano County, and a number of informal locations. The ten formal locations are described in Table 3-1.

Table 3-1: Park and Ride Facilities

City	Location	Spaces
Benicia	East Second St. & East S St. at I-780	15
Cordelia	Green Valley Rd. at I-80.	65
Dixon	Market Lane at Pitt School Road	89
Fairfield	Magellan near West Texas at I-80	400
Fairfield	K-Mart at North Texas & Air Base Parkway	55
Suisun City	Main St. at Route 12	82
Vacaville	Cliffside at I-80	129
Vacaville	Davis St. at I-80	250
Vallejo	Benicia Rd. at I-80	13
Vallejo	Curtola Parkway and Lemon St. at I-80	450
Vallejo	Magazine St. at I-80	21
Source: Solano Transportation Authority (website)		

Vallejo maintains a large park-and-ride lot at the ferry terminal, and a medium-sized lot at the York and Marin Transit Center. Surveys indicated that the Curtola, Suisun City, and Vacaville Regional Transportation Center lots were full, with some spillover parking on adjacent streets.[2] In particular, the Curtola park-and-ride lot seriously lacks capacity. Since this survey, the economic downturn appears to have slightly reduced demand, but the Curtola lot continues to be oversubscribed, and the Suisun City lot also continues to have overflow demand. Typically, 20 to 30 cars are parked at each of the informal Red Top Road and American Canyon Road I-80 interchange park-and-ride areas. Commuters also park in private off-street parking lots and along public streets near popular bus routes.

[2] Surveys were conducted in September 2000. More recent surveys were not available.

Intermodal Bus Transit Oriented Centers

The proposed intercity bus service plan described in Chapter 2, might be most attractive to passengers if delays at interchange bus stops are minimized without losing pedestrian and local feeder bus connections to the freeway intercity bus stops. Desirably, the freeway bus stops should function much as do station stops serving passenger rail services. These bus stop locations include:

- I-80 and North First Street in Dixon;
- I-80 and I-580 in Vacaville;
- I-80 and West Texas in Fairfield Transportation Center;
- I-80 and I-680 in Cordelia;
- I-80 and I-780/Curtola in Vallejo; and
- I-680 and Lake Herman Road in Benicia.

Ongoing planning for the I-80/I-680/SR-12 interchange, located in Cordelia, should specifically explore opportunities for the integration of an express bus transit center into its design. The North Connector Road provides the best opportunity for this new transit hub. This location could efficiently serve nearly all of the proposed new intercity routes, including the new Highway 12 route and new Sacramento express bus route.

Intermodal Ferry and Rail Center Facilities

Solano County presently has one passenger rail station and one ferry terminal. The City of Fairfield and City of Vacaville are working with the STA in the planning of a second passenger rail station. As for ferry services, the Baylink ferry terminal in Vallejo has plans for major improvements, which will include added parking and bus transit interface improvements. Planning for the expansion of the parking facilities at the Suisun City Station is also in its advanced stages.

Figure 3.2 shows the approximate locations of the existing transportation facilities within Solano County.

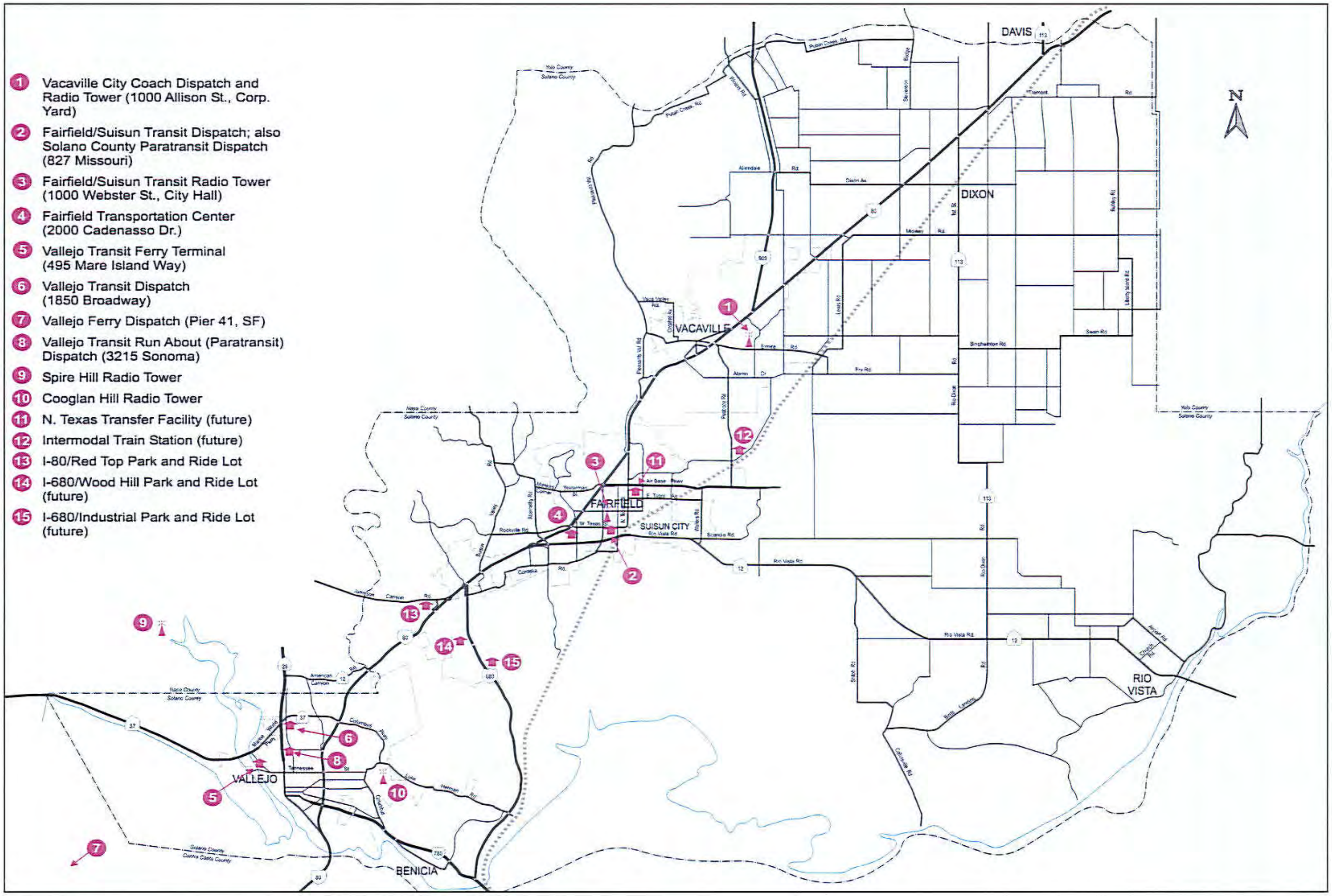


Figure 3-2: Existing Transportation Facilities

4. NEEDS ASSESSMENT

Along with evaluating the existing Transit ITS equipment/systems deployed in the County, another key step in beginning a Transit ITS plan is to assess the users' needs. As a first task, it ensures that the resulting Program will be needs-driven rather than technology-driven. To accomplish this goal, this was divided into two sections:

1. Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis
2. Stakeholder interviews

The purpose of each of these items and the results are described in the sections below, followed by a summary of the identified needs.

SWOT Analysis

As the title indicates, this analysis is used to identify internal strengths, weaknesses, opportunities and threats (SWOT) that may positively or negatively affect the deployment of the Transit ITS Plan in Solano County. For each item a suggestion had to be made as to how the corresponding strength, weakness, opportunity or threat would be addressed.

- For each strength identified, a suggestion was needed on how to capitalize on that strength.
- For each weakness, a suggested improvement plan was needed.
- For each opportunity, a suggested action plan was required.
- For each threat, a suggested preventative measure was needed.

The strengths, weaknesses, opportunities, and threats identified are summarized in Tables 4.1 through 4.4.

Strengths

The transit operators in Solano County have several strengths that enhance the transit system in the region as well as provide a solid foundation for improving the transit system through intelligent transportation systems. The strengths are summarized in Table 4.1.

The region has a solid institutional framework already in place called the Solano Transportation Authority (STA) SolanoLink Consortium, which brings all the transit management staff together to coordinate intercity transit issues. The mainstreaming of transit ITS projects in Solano County could be achieved through informing the consortium of the benefits of ITS and how ITS transit projects can increase the efficiency of the operations of their transit systems. Also, the region has strong cooperation between cities and a multi-modal system in place that involves BART, Vallejo ferry, park and ride lots, and the regional transit system. The number of regional transit routes between cities indicates their willingness to work together for the benefit of the public. Another strength of the region is the opportunity to capitalize on the planned AVL and TPC System currently being designed. Building on the success of this regional system will facilitate attracting more funding for new transit ITS improvements.

Table 4-1: Strengths

Strength	How to Capitalize on Strength
Solano Transit Operators have an existing institutional framework with the SolanoLinks Consortium.	Need to mainstream Transit ITS in Solano County using the SolanoLinks Consortium.
Existing inter-City Cooperation and relationships	Attract future regional/federal funding.
On-going ITS projects	Coordinate efforts when possible, build on current success
Existing regional system in place	Enhance operations of the fleets and incorporate ITS elements
Brand new Fairfield Transportation Center (FTC)	Incorporate ITS elements into the new center
The AVL and TPC System is underway	Build upon momentum-promote early successes
Core multi-modal system is already in place – BART, Ferry, Park and ride lots, City transit	Coordinate with all stakeholders
Dedicated and motivated staff	Involve all staff in planning and design effort
City of Fairfield leadership	Involve all key stakeholders in planning and design effort
Open to high technology change	Training, education and standards utilization
Old radio network for some cities in Solano County	Build state-of-the-art communication systems, limited legacy system integration required
Initial funding already in place	Show early benefits to secure more funding

Weaknesses

One of the weaknesses that could be improved is that there is not a strategic plan for transit or transportation for the County in-place. The development of this Countywide strategic plan will provide the framework for future ITS projects and guide the region for seeking future funding for transit ITS projects into the next twenty years.

Also, a private/public partnership is lacking in the County. The partnership with the private sector could provide additional funding for future projects, as well as increase public awareness among stakeholders and the private sector of the current transit ITS projects in the region. The public awareness could be increased through marketing strategies, newsletters, radio, television, and sponsored public functions.

Even though there is strong cooperation between agencies in the County, the real-time coordination among transit operators could be improved. The transit schedules of the regional transit routes as well as the transit schedules of each city do not appear to integrate with each other. The AVL and TPC Systems could be used as a platform to elevate coordination between agencies as well as building the coordination as part of the strategic plan.

Another weakness to improve is there is no dedicated operations and management (O&M) funding in the County for ITS projects. The budgeting of funding for O&M should be built into future programs and other capital improvement transportation projects.

Table 4-2: Weaknesses

Weakness	Suggested Improvement Plan
No Strategic Plan for transit or transportation for the County	Develop County-wide ITS Strategic Plan
Private/ Public Partnership	Investigate how to engage private sector
Not all agencies are participating fully	Build consensus, develop buy-in into the program and encourage participation
Lack of ITS infrastructure	Install infrastructure
Coordination among transit operators	Use AVL system as a platform to elevate coordination
Project awareness among stakeholders	Public awareness campaign, marketing strategies, newsletters
Keeping up with technology	Training, involvement in ITS arena
Lack of real-time coordination between transit operators	Build as part of the Strategic Plan
Limited system integration	Build multi-modal system
No dedicated O&M funding	Ensure O&M funding built into future programs

Opportunities

There are several opportunities for the region to act on and plan for transit ITS systems. One of the opportunities is to secure funding by developing an implementation plan for ITS and seeking funding mechanisms such as AB 1600, SAFETEA, TFCA, FTA and a regional sales tax. Also, by becoming one of the first transit ITS projects in the County to showcase the AVL technology will provide nationwide recognition to the region and promote other ITS transit projects that the County would implement in the next phase of the program.

The SolanoLinks Consortium is an asset for the region to develop contacts, develop O&M agreements, cooperation agreements, and strengthen the coalition of the County for lobbying for funding from the state and federal government. Another agency that would benefit the County is BART. The region needs to prove to BART that the Solano County Transit ITS Plan is in their interest from a multi-modal viewpoint and integrating BART with the Solano County Transit ITS Plan will provide opportunities for increased ridership, transit information, and a partnership for seeking future funding for the region. As stated earlier, the development of the strategic plan for transit ITS as well as transportation systems will be a blueprint for the County to build consensus and use for securing additional funding, as well as buy-in into the program.

Another opportunity for mainstreaming ITS into the region is to add ITS components into ongoing capital improvement projects. Building on the existing infrastructure will decrease future ITS construction costs, as well as expand the ITS system in the field for transit applications quicker than applying for funding through grant applications and designing and constructing the new ITS projects. The Solano County Smart Corridor Plan is an example of one project where it would be advantageous to attach onto the planned infrastructure for transit ITS projects in the County. Another agency's infrastructure, such as Caltrans, would also be ideal for sharing and expanding the transit ITS projects in the County.

Finally, understanding the lessons learned from other AVL and TPC Systems deployments by contacting other agencies with past and present systems will help reduce the risks in the project and encourage integration with the existing systems.

Table 4-3: Opportunities	
Opportunities	**Suggested Action Plan**
Funding	Secure funding by developing a program plan
Deploy AVL systems throughout the region	Tap into city funding within the region
Existing AVL and TCP systems elements in place	Build and complete architecture for Transit ITS.
Become one of the first projects in the County to showcase the AVL technology	Gain nationwide recognition and promote other ITS Transit projects
SolanoLinks Consortium	Keep them involved – develop agreements and contacts
BART	Prove that Solano County Transit ITS Plan is in their interest
Development of a Strategic Plan	Utilize to secure additional funding, buy-in into the program, build consensus
Number of on-going improvement projects	Mainstreaming ITS
More matured AVL system technology in the marketplace	Build upon current national success
ITS Standards	Build provisions into the program to assure additional funding
FTA visibility	Build upon the visibility
Solano County Smart Corridor Plan	Take advantage of the infrastructure for Transit ITS projects in the County
Lessons learned from other AVL system deployments	Contact other agencies with past and existing AVL systems to reduce risks in the project, encourage integration.
Use Caltrans Infrastructure	Coordinate with Caltrans' staff

Threats

There are several threats that could limit the effectiveness of the program. The threats could be prevented through several measures. One of the threats is the cost of the program. However, by mainstreaming ITS into existing capital improvement projects, the cost can be reduced. Also, costs can be reduced if future funding is proactively sought through lobbying.

Another threat is the lack of O&M funding. The funding for O&M would need to be built into the program as well as appropriated for in funding mechanisms such as AB 1600 developer fees, local sales tax, regional sales tax, and other funding sources. Also, funding for additional staffing would need to be budgeted for to assure that the AVL and TPCS systems are managed effectively.

The perception from the public and the politicians that the AVL and TPC Systems will not decrease traffic congestion is another threat to the program. However, the threat could be prevented if the program records benefits, highlights the early results and manages the expectations of the public and politicians. Also, the politicians do not have the AVL and TPC Systems high on their priority list. However, a large public awareness campaign, different marketing strategies, newsletters, and spreading the word about the transit ITS program through the City's intranet could bring the program to the forefront of the city's agenda.

Another threat is the region is focused on the highway improvements instead of transit, which could draw funding away from the transit projects. One preventive measure is to aggressively seek funding from the FTA for future transit ITS projects in Solano County and showcase the region's initial deployment of the AVL and TPC Systems in the industry.

Table 4-4: Threats

Threats	Preventive Measures
Cost	Mainstream ITS, assure future funding by proactive lobbying
O&M	Assure O&M funding built into the program
ITS institutional framework	Nurture cooperation through SolanoLinks consortium and beyond. Build into the program
Increase traffic congestion	Record benefits, manage expectations, highlight early results
Staffing	Budget for increase staffing to assure managing AVLS system
AVL systems not on the priority list for some politicians	Public awareness campaign, marketing strategies, newsletters and City's Intranet
Highway focus of the region may draw some funds away from transit	Aggressively seek FTA funding for future Transit ITS projects in Solano County
System integration and coordination	Assure it is built into "Mega-Project" activity
Lack of public support	Public awareness campaign, marketing strategies, newsletters and City's Intranet
Expectations	Assure meeting expectations, educate public, not over promising

Stakeholder Interviews

DKS contacted the main stakeholders of the Solano County Transit ITS program to assess the user's needs. The approach we took was to interview some of the affected stakeholders as well as conduct workshops and presentations with several of the main stakeholders. The stakeholders we met with to discuss their needs were:

- City of Fairfield
- City of Vacaville
- City of Suisun
- City of Vallejo

Two workshops were held at the City of Fairfield and the City of Vallejo and two presentations made at the STA monthly board meetings. Minutes of the meetings are included in the appendix for your information.

At the City of Fairfield workshop, the City of Vallejo was concerned about the benefits of the project and wanted more examples of successful AVL systems. Also, the Cities of Vallejo and Fairfield were interested in a countywide AVL system that would allow a transit operator at each TMC to be able to see all other agency buses in the system. The feedback from the workshop stakeholders was focused mainly on the priority of the initial phase of the project providing operational improvements rather than traveler information such as kiosks. The stakeholders felt that kiosks and information signs could be provided in future phases of the program. Also, the City of Vacaville was interested in the "talking bus" module for installation in their buses for assisting the visually impaired riders.

A concern expressed at the City of Vallejo workshop was the amount of time and dollars they might need to commit to this project, and that the $10 million cost estimate will increase over time with technology changes and improvements requiring costly upgrades in the future.

The City of Vallejo sees positive aspects of implementing a AVLS/TPCS for Vallejo Transit, but expressed strong concerns regarding capital and maintenance costs. Funding for City of Vallejo Transit will be tight and they cannot make additional financial commitments at this time. There are several other un-funded capital project priorities that would be ahead of the AVLS/TPCS.

The City of Vallejo views on-going maintenance costs to include both hard and soft aspects. Hard costs include software licensing and upgrades, physical part replacements and other maintenance costs. Soft costs include additional staff time, new training, and other similar costs. The City of Vallejo would like to see a detailed breakdown of the AVL system and how its implementation would be phased. The RFI under development to AVLS/TPCS operators should include information on operation and maintenance costs. There was some discussion regarding moves in funding for O&M (future county sales tax, TEA-21), but none of this is currently secured.

Some of the concerns at the STA workshop were that the system should be capable of all functions available, but each jurisdiction should have the choice of which function to "turn on" at an appropriate time. Also, the stakeholders felt that the initial phase should include dispatch upgrades and for functions to be added as each phase proved itself. The City of Vallejo expressed concern regarding the cost of the operating system upgrades necessary to support the system and requested that the RFI include operations and maintenance costs of deployed systems.

The stakeholders also wanted the system to use the existing City communications infrastructure for center-to-transit vehicle communications to avoid recurring costs. Another concern was that the system should provide an interface with TransLink and also integrate with TravInfo.

Special ITS Needs in Solano County

The Solano County Transit ITS Plan will need to address some special transit needs of the County. Some examples are discussed below.

- Solano County does not have a regional Transit Management Center, and most cities of Solano County do not have a TMC.
- Some cities do not have EVP installed.
- Local dispatch communications are generally confined to within each city's limits. Communications between dispatch and inter-city transit vehicles are limited.
- Heavy congestion at the I-80/I-680 interchange and the Carquinez Bridge severely affects intercity transit service.
- Intercity services interface with transit services outside the County (e.g., BART, MUNI).

Solano County Transit Operators need to partner with MUNI, Caltrans, TravInfo, and various other local, regional and state agencies and organizations involved in transportation-related services. Efforts are underway regionally to build a communications system throughout the Bay Area that will link all such systems.

5. CONCEPT OF OPERATIONS

The Concept of Operations for the Solano County Transit ITS Plan presents a long-range (20-year) vision of Intelligent Transportation Systems (ITS) for transit elements in Solano County. Of particular focus are the high-level integration aspects between the transit operators within the County. While this report includes some elements of the Automated Vehicle Location System (AVLS) and Transit Priority Control System (TPCS) Concept of Operations report, it is broader in nature, identifies more of the high level functions and features, and looks to the deployment of ITS technologies for transit systems over a longer period of time.

The Concept of Operations describes the application and integration of technology to enhance transit operations within Solano County in the following areas:

Transit Management Systems - communications and control technologies that improve the overall planning, scheduling, and operations of transit systems;
Advanced Traveler Information Systems (ATIS) - providing real-time information to transit riders to make better informed decisions regarding their mode of travel and planned routes;
Electronic Fare Payment Systems - automate fare payment for more convenience for transit users; and
Demand Responsive Dispatch Systems - enhanced demand-responsive dispatching for more efficient operations.

Key Stakeholders

As part of the development of the Solano County Transit ITS Plan, key stakeholders have been identified. These stakeholders represent the transit operators within the County who have a vested interest in the design and deployment of the Solano County Transit ITS Plan. The stakeholder agencies include:

- The City of Fairfield
- The City of Suisun
- The City of Vacaville
- The City of Vallejo
- The City of Benicia
- The City of Dixon
- The Town of Rio Vista
- Solano Transportation Authority

Transit Management Systems

Transit Management Systems refer to a broad range of advanced public transportation systems designed to improve the planning, scheduling, and operations of transit vehicle fleets. These technologies include:

- Advanced Vehicle and Control Center Communications Systems
- Automated Vehicle Location (AVL) Systems
- AVL Sub-systems elements, such as Transit Priority Control (TPC), Automated Passenger Counters (APC) and Automated Audio Annunciation Devices.

Advanced Vehicle and Control Center Communications Systems

A key part of the integrating ITS into Solano County's transit system is a mobile communications network which provides communications between transit vehicles and dispatch centers. Due to the mobility of transit vehicles, radio or other mobile technology is used by vehicles to dispatch communications. This communications may include two-way data messaging or a combination of data and voice communications.

To ensure coordination between the various transit operators, a communications network will link the individual dispatch centers to each other and, possibly, to existing or future Transportation Management Centers (TMCs). Information such as the current location and current status of the transit vehicles, and status of the roadway network, will be shared with all centers across this network. Center-to-center communications may be through a fixed wire line, such as a fiber optic cable or T-1 connection, or through wireless communications, such as radio or cellular phone. The dispatch centers may be linked in an either linear-configuration network (Figure 5.1), a ring-configuration network (Figure 5.2) or a star-configuration network (Figure 5.3).

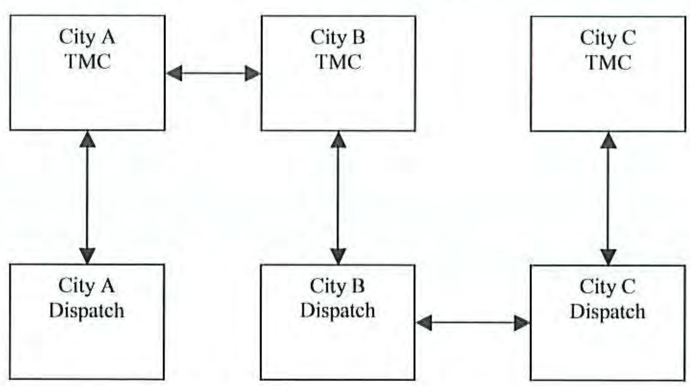


Figure 5-1: Linear Configuration

In a linear configuration (Figure 5.1), each center is connected to another center (which may be in the same city or a different city) and all centers communicate with each other along a straight line. The main disadvantage is of this type of configuration is that any break in a communications link between two centers affects the communications for all downstream centers. For example, a break between the City B TMC and City B Dispatch would prevent data from being shared between City C and City A.

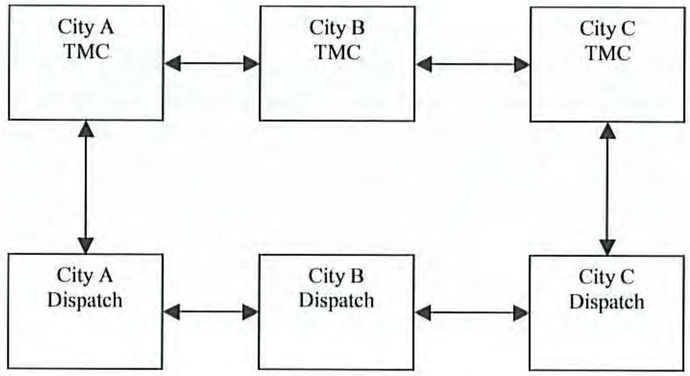


Figure 5-2: Ring Configuration

A ring-configuration network (Figure 5.2) is more robust than a linear-configuration network, since there are two communication paths between each pair of centers. As with the linear configuration network, data is shared among all the centers via the communications ring. Data travels in one direction around the network. However, if there is a break in communications, data will flow in the reverse direction to its destination.

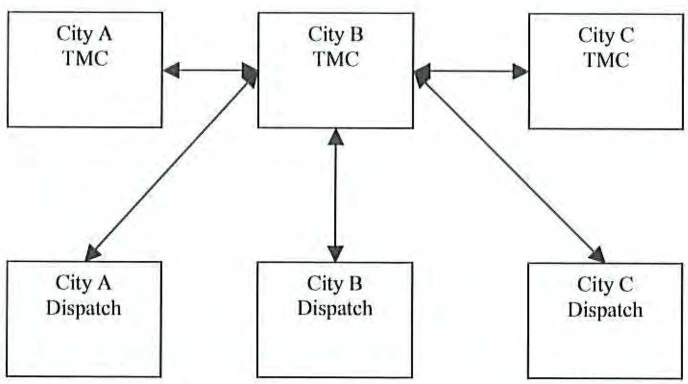


Figure 5-3: Star Configuration

Another option is to connect all the transit operators in a star-configuration to one of the centers as shown in Figure 5.3. This center would serve as a central repository of information for the system and coordinate the sharing of data between agencies. The center could also be the main point of communications and coordination with transit agencies located outside the system.

Automated Vehicle Location (AVL) Systems

Automated Vehicle Location (AVL) systems track the location of the transit vehicle and transmit that information over a mobile communications system to a central facility. The actual transit vehicle position determination and the position relay techniques vary, depending on the requirements of the transit agency and the technologies selected. The main vehicle locating technology used today in transit applications is the Global Positioning System (GPS). Typically, vehicle position information is stored on the transit vehicle for a short time, ranging from a few seconds to several minutes, before being transmitted to the transit agency's dispatch or control center. In some cases, the position information can be stored on board the transit vehicle and retrieved at the end of the service day for record-keeping and analysis. The near real-time tracking of the transit vehicle allows the transit dispatch centers and transit managers to know the location of the transit vehicle at any given time. Using this information, the dispatch centers and transit managers can respond to real-time situations and make informed decisions that will improve the safety, overall efficiency, and performance of the transit system.

For example, if transit vehicle 'A' was going to be late for a scheduled transfer with transit vehicle 'B', the AVL system would allow dispatch to anticipate the arrival time of transit vehicle 'B,' and determine whether transit vehicle 'B' should be held at the transfer point.

Over the past decade, there has been a widespread application of these technologies in the United States and Canada. Most of the applications involve the integration of advanced vehicle and control center communication systems with AVL systems. Recent studies indicate there are at least 75 transit systems in the U.S. and at least six Canadian transit authorities that have AVL systems operational, under installation, or under planned implementation.

Other AVL Subsystem Elements

There are several other AVL subsystems elements that can be added to transit vehicles AVL system capabilities. With the advancement of technology, new enhancements are deployed every three to four years, and the hardware and software systems would need to be upgraded as additional subsystems and features become more cost-effective. With the pace of technological advancements, it is anticipated that the equipment in transit vehicles may need to be upgraded every five years, and that transit agencies should perform technology assessments every three years or so.

Smart Bus

With the advancement in technology for transit operations, one concept known as the Smart Bus in piecing all of these on-board technologies together to form an intelligent transit vehicle. A Smart Bus simply contains advanced vehicle components to better serve the users of the system and the operators of the system while maintaining a high level of efficiency for the transit system as a whole. Some of the on-board elements or subsystems include:

- Transit Control Priority;
- Automated Passenger Counters; and
- Automated Audio Annunciation Devices.

Transit Control Priority (TCP)

The near real-time positions of transit vehicles or other information (such as schedule adherence) may be relayed to a local city's TMC directly from the transit vehicle; or indirectly through a dispatch center or a roadside controller as an input to a Transit Priority Control System. Based on pre-determined criteria regarding the schedule adherence of a particular transit vehicle, the City's TMC may implement traffic signal timing plans to facilitate traffic flow on particular corridors to improve the schedule adherence of transit vehicles. Figure 5.4 illustrates a possible configuration of a Transit Priority Control System as it relates to an AVL system and Traffic Management System.

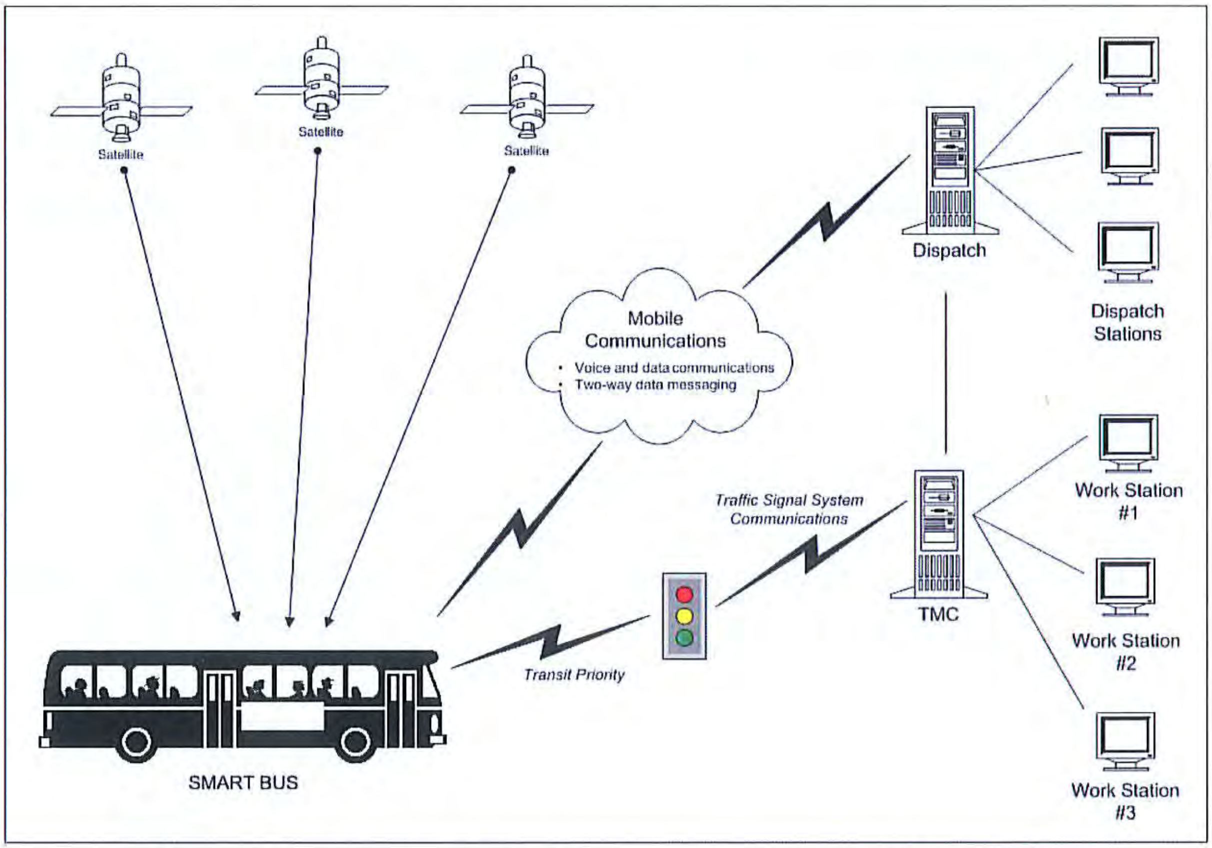


Figure 5-4: Transit Priority Control Integration with AVL

Automated Passenger Counters (APC)

The technologies employed in automated passenger counting (APC) sensors include infrared beams and pressure sensitive treadles located at each door of the vehicle to detect a passenger boarding or exiting the vehicle. These passenger counts may be combined with the AVL system data to correlate the information to bus stops. The passenger count and location data is then transmitted either over the mobile communications network, or downloaded at the end of the day for processing. Automated software systems could be used to process this data for transit route planning, scheduling, and operations; ultimately reducing the schedule preparation time. The software system and an accurate database also enable planners and transit analysts to select more effective bus stop placements and generate much more accurate ridership counts. A properly implemented automated software system will improve the productivity of bus and staff in scheduling and planning.

Currently, APCs are utilized by at least twelve transit agencies in North America. At least twelve other North American transit agencies have discontinued the use of APCs. The primary reasons for abandoning APCs at these agencies have been high development costs and problems with accuracy, software development, and maintenance.

Automated Audio Annunciation Devices

Another subsystem that could be incorporated into a Smart Bus is an automated audio annunciation device that announces all major intersections, transfer points, and stops specifically requested by a passenger. These devices comply with ADA requirements, and reduce distractions and work load for the transit vehicle driver. The information can also be displayed on passenger information displays located inside the transit vehicle.

Future Enhancements

Other subsystem enhancements that have not been commercially deployed include devices that would allow Smart Buses to literally "read" the road (and objects around the vehicle), increasing safety and reducing the number and severity of collisions. These devices include longitudinal and lateral collision avoidance systems which sense impending head-on and rear-end collisions, as well as restraints and passenger safety devices that will automatically deploy in anticipation of imminent collisions. Other enhanced communications would allow the relaying of the status of the transit vehicle to maintenance facilities, for real-time monitoring. Figure 5.5 illustrates the some of the features of the Enhanced Smart Bus.

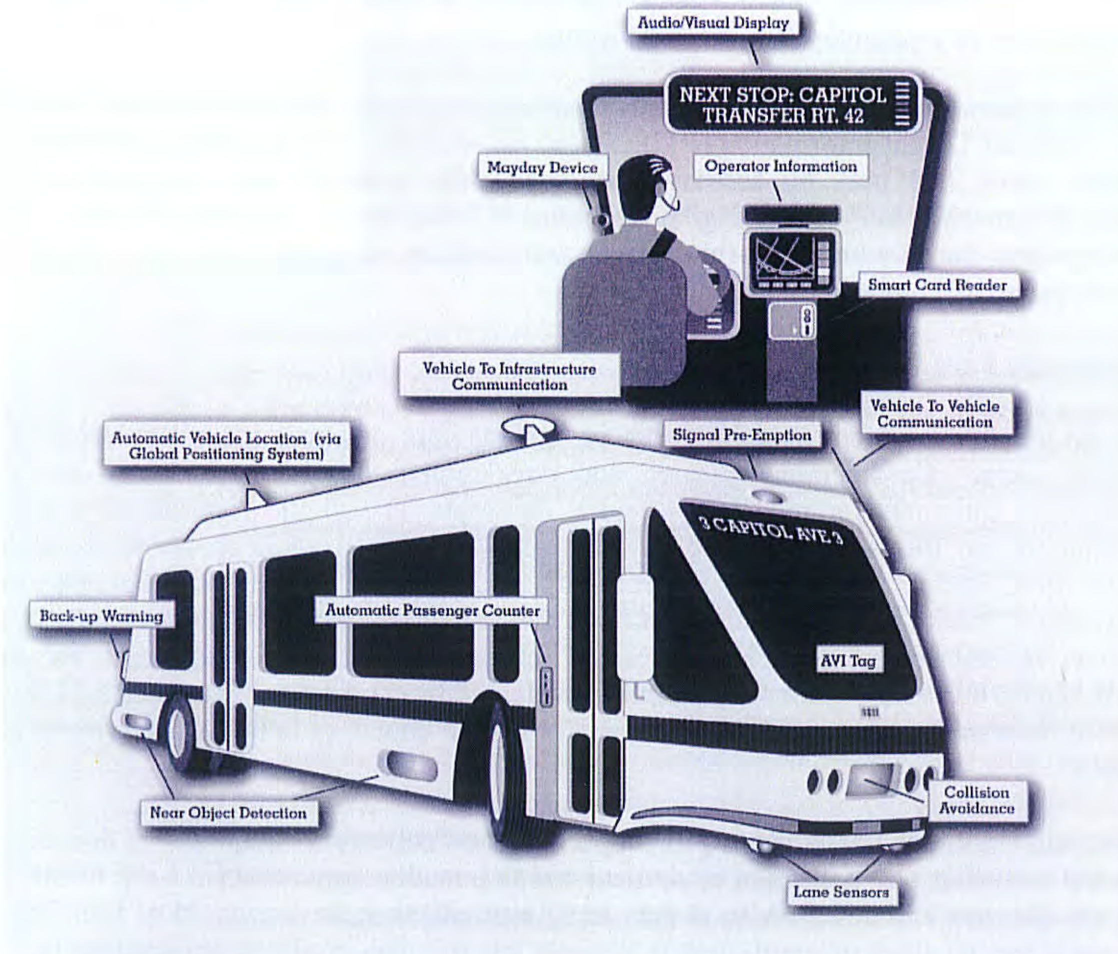


Figure 5-5: Enhanced Smart Bus

Advanced Traveler Information Systems

Advanced Traveler Information Systems (ATIS) include a broad range of advanced computer and communication technologies, designed to provide transit riders real-time information to make informed decisions regarding their mode of travel, planned routes, and travel times. ATIS have been found to be effective in promoting transit services to current and potential new transit patrons. They also provide a more convenient and a potentially lower-cost alternative for disseminating traveler information to transit riders. These systems include interactive kiosks or dynamic message signs at major transit destinations and transfer facilities (including park-and-ride lots); telephone information systems, and the Internet.

The first generation of transit information provides general information to a broad range of transit users, such as the display of predicted bus arrival times at a bus stop, or the publishing of bus schedule on-line. MTC operates a website (511.org) and TravInfo (an automated telephone inquiry system) provides transit information to the nine-county Bay Area public. If Solano County implements a regional transit information and dispatch center, this center could either provide information to these existing transit services, or create a new service focused on Solano County.

Future improvements in technology and communications may allow a whole new level of Personalized Transit Information (PTI). Based on accounts of user profiles submitted by transit users, PTI may be accessed, or proactively "pushed" by a regional transit information center to Personal Digital Assistants (PDAs), pagers, and in-car devices. The information may include real-time status and location of transit vehicles, delays or predicted arrival times in transit vehicles.

Electronic Fare Payment Systems

Electronic fare payment systems focus on making fare payment more convenient for transit users. Considerable research and development has been conducted in fare collection equipment and media over the last few years. Transit agencies and vendors are testing several forms of electronic payment including stored value cards, credit cards, debit cards, contact smart cards, and proximity smart cards. These technologies make the payment of transit fare more convenient and may allow the same transit ticket to be used across several transit agencies. Besides making transit more convenient for the passengers, these new technologies will provide additional data on passengers and their use of the transit system, so that transit service can be improved to better meet passenger needs.

The data communications needed to support the fare collection equipment is dependent on the particular fare collection equipment and fare media employed. Data can be stored by the fare box and downloaded at the end of a service day, or data could be transferred in real-time to other onboard storage devices; or, the data could be transmitted to the radio communications system for further processing. Fare data may be correlated with vehicle location data to be used for service planning purposes. Currently, most transit agencies that gather data from fare boxes do so by dedicated systems which probe the fare boxes when each vehicle returns to the garage. Fare boxes currently manufactured have limited, if any, capability for external interfaces.

Electronic fare systems are best suited for different transit systems that have many interface points. Several transit agencies in Solano County have routes that interface with other modes (e.g. ferry) or agencies that provide regional service. These include Benicia Transit (paratransit service meets with Vallejo RunAbout to provide service to Fairfield/Vacaville); Vallejo Transit (connections to Fairfield Suisun Transit, Bay Area Rapid Transit System (BART) system and San Francisco Municipal Railway (MUNI) system), and Fairfield/Suisun Transit routes to BART system. The implementation of a region-wide electronic fare payment system would enhance the regional transit system. The Metropolitan Transportation Commission (MTC) TransLink project is currently testing a stored value card that is usable for fare payment on several transit systems. Solano County transit operators may decide to adopt this platform as part of the Solano County Transit ITS plan.

Demand Responsive Dispatching

The use of ITS can also improve the operations paratransit systems that provide specialized transportation services to many groups of citizens (e.g., the elderly and the disabled) that require specialized transportation services not readily available by fixed-route systems. Combined with improved communications systems, AVL systems and computer-aided dispatching software, passenger trip requests can be more efficiently scheduled to reduce the amount of staff time and effort needed. Passenger trip reservations that are now recorded on an answering machine and processed manually 24 hours before the trip could be scheduled and confirmed in real-time with the new system. Passengers see improved service and convenience in the form of improved response to trip requests, more accurate estimates of predicted pickup/drop-off times, increased flexibility in the scheduling of desired services, and reduced trip travel times.

Implementation

Figure 5.6 illustrates the many elements of Solano County's Transit Intelligent Transportation System. In this example, a Vallejo Transit fixed-route bus maintains communications with the Vallejo Dispatch center, which relays real-time information about engine performance to the Vallejo Maintenance Department. Also, the bus would communicate with the Vallejo dispatch center and the Ferry system for real-time bus arrival and departure information. Proximity sensors provide information about the buses surrounding environment. The bus also communicates with Fairfield Dispatch while operating within the Fairfield city limits. If the bus is behind schedule, it may request transit priority over the City of Fairfield signal system. Both the Fairfield Dispatch and Vallejo Dispatch provide information to local transit riders via kiosks, signs and their local websites. In addition, Fairfield Dispatch also serves as a regional transit coordination center and feeds this information to BART and 511.

As can be seen from this example, the implementation of the Solano County Transit ITS program will be carried out by a broad spectrum of agencies within the County in a very complex environment. The program requires multi-agency involvement, consensus and initiatives to provide a system-integrated approach that benefits all. This is particularly important for those elements that are dependent on one another.

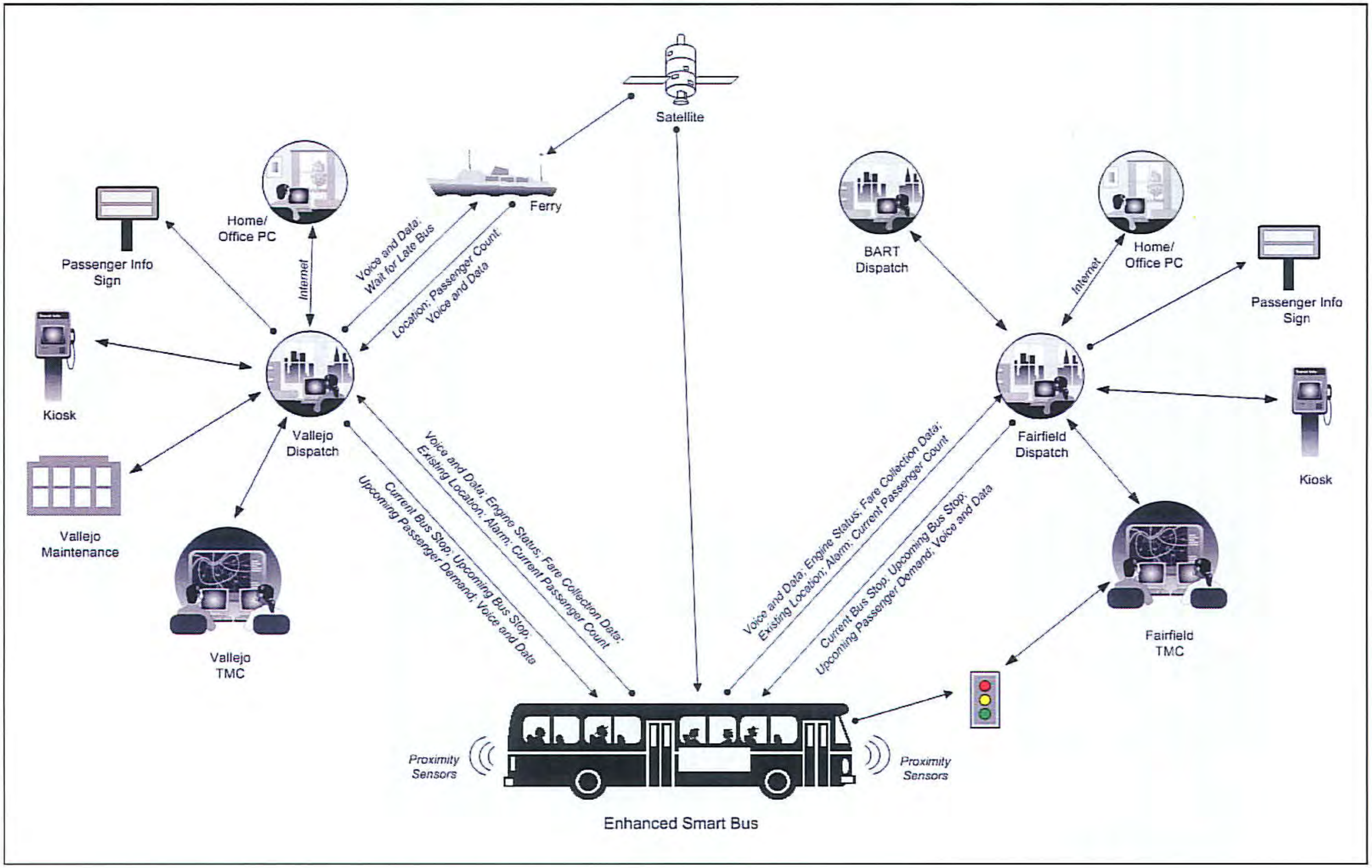


Figure 5-6: Intelligent Transportation Systems for Transit Sample Network

An implementation framework need to be determined, based on the input of the transit operators of Solano County of an ultimate Transit ITS vision. This framework provides a direction for ITS deployment and shall be considered as a management tool to assist the transit operators in securing future funding and project planning.

Based on this framework, a list of prioritized projects can be created and used as a management-planning tool to develop future market packages. The staging of projects in the Solano County Transit ITS Strategic Plan must be viewed as flexible enough to make adjustments to respond to funding opportunities and changing circumstances.

Opportunities for funding and implementation for Solano County Transit ITS program projects may not be as obvious as for traditional transportation improvement projects. The County needs to be as flexible as possible in developing future projects. Complex circumstances may require the County to choose different projects out of the project priority list in different parts of the County. Obviously, highest priority will be given to build communication infrastructure, and those projects that provide early benefits to the end-user. In some cases, ITS application may be best implemented as additional elements to conventional improvements project or others infrastructure upgrades. This suggests that the implementation plan will need periodic upgrades.

6. SYSTEM ARCHITECTURE

The primary objective of this chapter is to "de-mystify" the National ITS Architecture and translate its components into practical applications tailored to the transit operators within the County of Solano. Basically, the National ITS Architecture provides the common framework or "blueprint" from which to plan and/or design each ITS element of the system so that it is compatible and that its operations are coordinated. This chapter presents an overview of the Architecture, highlighting key points, and providing an initial level of detail to further illustrate how useful the Architecture is to the ITS practitioner at the project level.

What is the Architecture?

In its most basic form, architecture is a set of rules that facilitates the building of systems, and allows the systems to communicate and inter-operate after being built. An ITS architect is to an ITS system as a building architect is to a building. A building architect could not build a structure without a set of plans. As such, an ITS architect cannot build a complex ITS environment without a set of plans. These "plans" are the System Architecture. It is important to distinguish between an architecture built for planning and implementation guidance, and an architecture used to design and build actual working systems. In discussions regarding this Strategic Plan, the former context is most appropriate, although a few insights will be provided on the latter. This is because at the Strategic Plan level, the identification of the key stakeholders and communication links is first established through the planning architecture development process. As the actual phases of the overall system is built over time, more detail is provided to design and build the system.

What is the National ITS Architecture?

The following sections describe the essentials of the Architecture in terms of its basic functions and features.

What Does It Do?

Since 1992, the U.S. Department of Transportation (DOT) has been engaged in the development of the National ITS Architecture. Basically, it provides a framework and common vocabulary for planning, defining, and integrating ITS systems among different modes of travel and geographic areas. The set of tools that comprise the National ITS Architecture provide a framework to help the following tasks:

- Identify key stakeholders and their relationship;
- Describe required activities or functions;
- Define interconnections and interdependencies between functions; and

- Define a blueprint for integration of the systems and guidance to identify integration opportunities during project definition

Furthermore, Section 5206 (e) of the Transportation Equity Act (TEA-21) requires that ITS projects carried out using funds made available by the Highway Trust Fund conform to the National ITS Architecture, applicable provisional standards, and protocols. This is now more commonly referred to as "conformance" with the National ITS Architecture.

What Is It Made Of?

The National ITS Architecture's main objectives are to describe what functions and processes are needed, decide where these functions should be located, and identify who needs to be involved and/or is responsible. In short, the Architecture provides a foundation to develop a series of relationships within/between components, subsystems, and agencies. Within the Architecture, these diagrams represent sample figures that can be tailored to a specific area such as Solano County. In subsequent sections of this chapter, the specific components of the Architecture that are used to show the Solano County Transit ITS project's conformance to the Architecture are further defined and diagrams uniquely tailored. The principal components that make up the Architecture are described in Table 6.1:

Table 6-1: National ITS Architecture Component Description

Component	Description
User Services	Identifies current and future needs and/or services to address/implement
Market Packages	Pieces of the Architecture that provide particular transportation services Describes what functions to perform
Logical Architecture	Describes what functions/processes are needed Indicates data/information flows between functions/processes
Physical Architecture	Groups/allocates functions to subsystems Identifies the physical interfaces for which to develop standards
Organizational Architecture	Groups/allocates subsystems by agency ownership Describes who will be interconnected to one another for data/information sharing purposes
Architecture Flows	Identifies what data/information flows exist between subsystems
Subsystems	Transportation-related components that makeup the Physical Architecture Typically classified into four categories: center, roadside, vehicle, and traveler

Why Is It Useful?

Conformance with the National ITS Architecture ensures that transit ITS Projects in the County of Solano are eligible for future Federal funding.

The Solano County Transit ITS Program should make use of the U.S. DOT's investment in the National ITS Architecture to develop a tailored ITS Architecture that establishes a framework for deployment and guides Solano County Transit ITS Program stakeholders.

A countywide transit ITS Architecture has the potential to provide the following benefits:

- Ensure that ITS Projects meet TEA-21's Architecture conformance requirements for Federal funding eligibility through MTC and Caltrans;
- Lower costs and risk, during both the design and over the entire project life-cycle;
- Reduce development timeframe and allow for seamless integration of systems;
- Orderly and efficient expansion of systems/technologies;
- Economies-of-scale by using technologies from multiple vendors that can still work together as a system;
- Use of a common set of standards to better coordinate operations, integrate systems, and share data/information;
- Identify potential stakeholders interested in sharing data/information, thereby assisting in the current and future project planning and implementation process; and
- Allow for more coordinated operations among different transit operator agencies within the City.

Conformance with National ITS Architecture

This section discusses the issues that surround conformance with the National ITS Architecture and how this relates to standards and interoperability.

What Is the Reason for Architecture Conformance?

As it has been shown, the National ITS Architecture is a common framework for the design and implementation of ITS. Because of its strategic role, TEA-21 requires the U.S. DOT to ensure that Federally-funded ITS Projects conform to the National ITS Architecture and approved standards. Conformance with the National ITS Architecture means the use of the National ITS Architecture is required in developing a regional and local implementation plan of ITS elements, referred to as a Regional ITS Architecture and a Local ITS Architecture, respectively. This includes the subsequent adherence of all ITS projects to that Regional ITS Architecture. Development of the Regional ITS Architecture begins with the transportation system planning process and the development of an ITS Strategic Plan or integration strategy. The Regional ITS Architecture is expected to guide the development of specific projects and programs within the County.

What Is Expected From Project Conformance?

During project implementation, the following results are expected from a project conformance analysis:

- The project specifications shall ensure that the project accommodates the sharing of electronic information and provides for the functionality and operations (both at the time of project implementation and in the future) between the agencies and jurisdictions as indicated in the Strategic Plan and Regional ITS Architecture (To be developed in the near future).
- The project shall use applicable ITS standards that have been officially adopted by the U.S. DOT.
- The ITS standards that are pertinent to the project should be used as they become available, prior to adoption by the U.S. DOT.

How Was The Local Architecture Developed?

Figure 6.1 illustrates how the National ITS Architecture was used to develop an ITS Architecture for the Solano County Transit ITS Program. Basically, the first column (or Activity) represents the steps taken; the second column (or arrows) represents the part of the National ITS Architecture that was used, and the third column (or Product) represents the deliverable.

The basic process used to develop the Solano County Transit ITS Program Architecture is as follows:

- Inventory existing ITS;
- Map existing and planned ITS to the Architecture;
- Identify the desired connections between Agency systems; and
- Tailor data/information flows between systems.

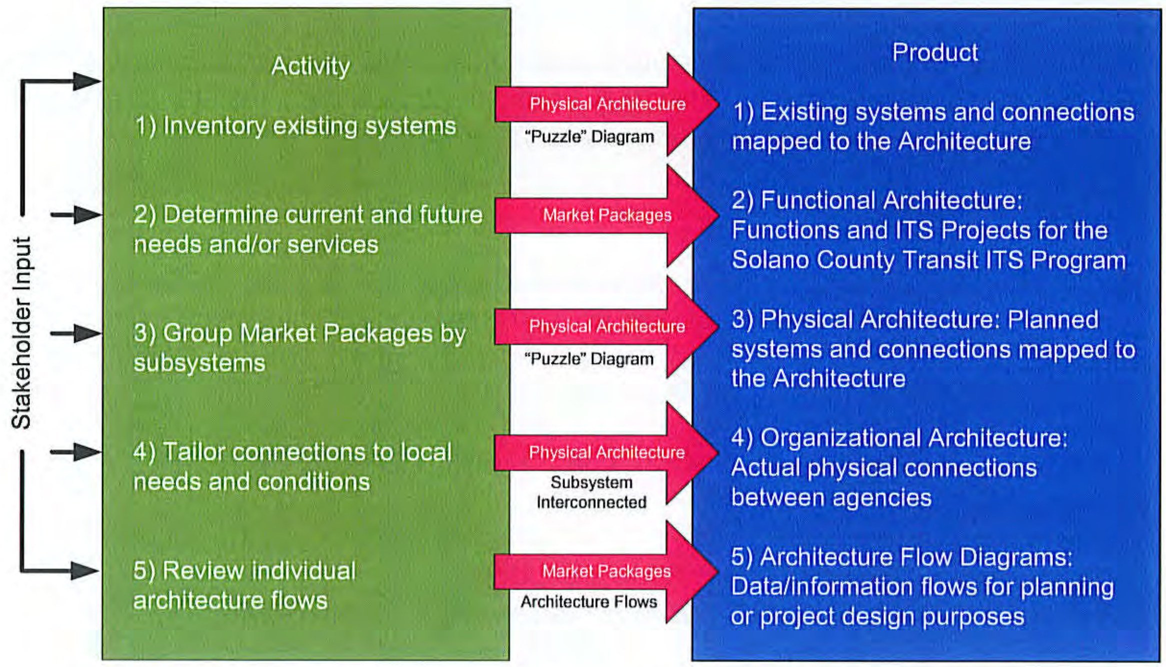


Figure 6-1: Mapping the National ITS Architecture to the Local Architecture

Solano County Transit ITS Architecture

The Solano County Transit ITS Architecture is a description of "what" we want to do in the County of Solano. Figure 6.2 shows the planned ITS services and functions, incorporates the relevant subsystems and organizations, and describes the information exchanges planned between them illustrated through a Physical Architecture. These relationships are illustrated by tailoring specific National ITS Architecture diagrams to the needs of the transit operators in Solano County. From these tailored diagrams, a deployment plan structure is established that provides a basis for long-term transportation systems planning in the region. Then, mainstreaming ITS Projects into the planning process and promoting stakeholder buy-in across organizations should be easier since everyone is working from the same blueprint.

Components of the Architecture

The following sections provide a detailed description of the specific components which make up the Solano County Transit ITS Program Architecture; that is, the Physical Architecture, Organizational Architecture, and Architecture Flow Diagrams.

Physical Architecture

The Physical Architecture's primary purpose is to group and allocate the Solano Transit Operators' selected functions (or Market Packages) to physical subsystems. Once this is complete, the Physical Architecture then provides the initial look at establishing the interconnections between various subsystems.

The Physical Architecture is useful to the Transit Operators' stakeholders for the following reasons:

Groups and allocates functions and ITS project ideas
Establishes the initial physical connections between Agency subsystems
Provides key materials/diagrams to establish conformance with the National ITS Architecture

The first job was to tailor the Physical Architecture diagram to reflect those subsystem components and interconnections selected for the entire Transit ITS Program. This is shown in Figure 6.2, the Solano County Transit ITS Architecture.

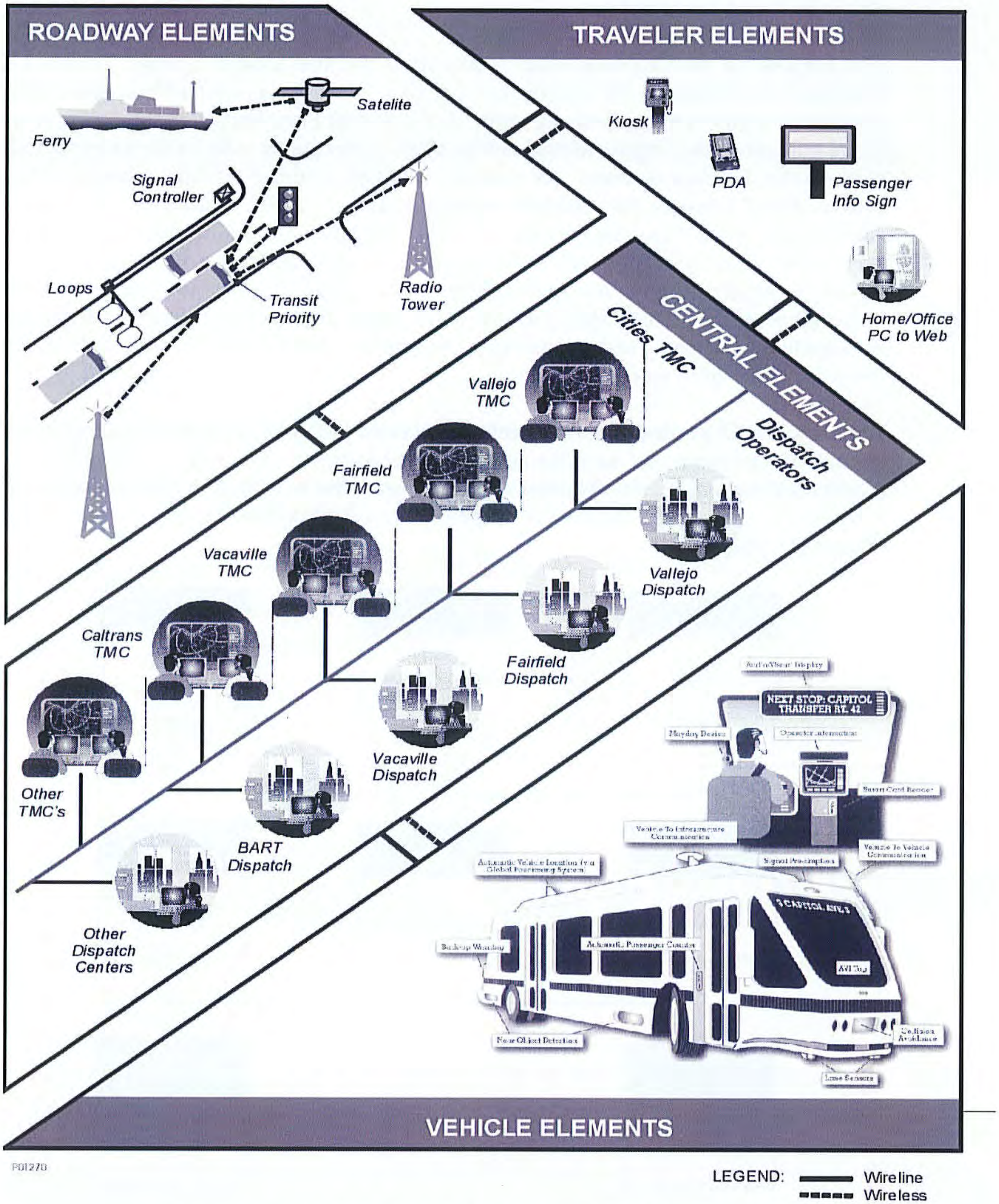


Figure 6-2: Solano County Transit ITS Architecture

Organizational Architecture

The purpose of an Organizational Architecture for the Solano County Transit ITS Program is to determine the connections between the various stakeholders, and will be prepared as some of the projects identified in the Action Plan proceed to the design stage. In the context of the Organizational Architecture, connections refer to the physical links between the different systems. As a result, the Organizational Architecture shows how data is shared between the different Agency systems. While developing the Physical Architecture in the previous section, an initial indication of who is the owning and/or responsible Agency is provided. The Organizational Architecture takes this one step further by explicitly grouping each subsystem by Agency ownership, establishing the actual physical interconnections (not just representative ones as provided in the Physical Architecture diagram), and graphically illustrating the Agency/subsystem hierarchy through a series of interconnect diagrams.

Basically, the Organizational Architecture diagrams look like a series of agency-owned systems linked/connected to other agency-owned systems. The key is determining the appropriate sequence(s)/relationship(s) that indicate who is talking to whom. Figure 6.3 illustrates a sample of a high level Organizational Architecture for the Solano County Transit ITS Program.

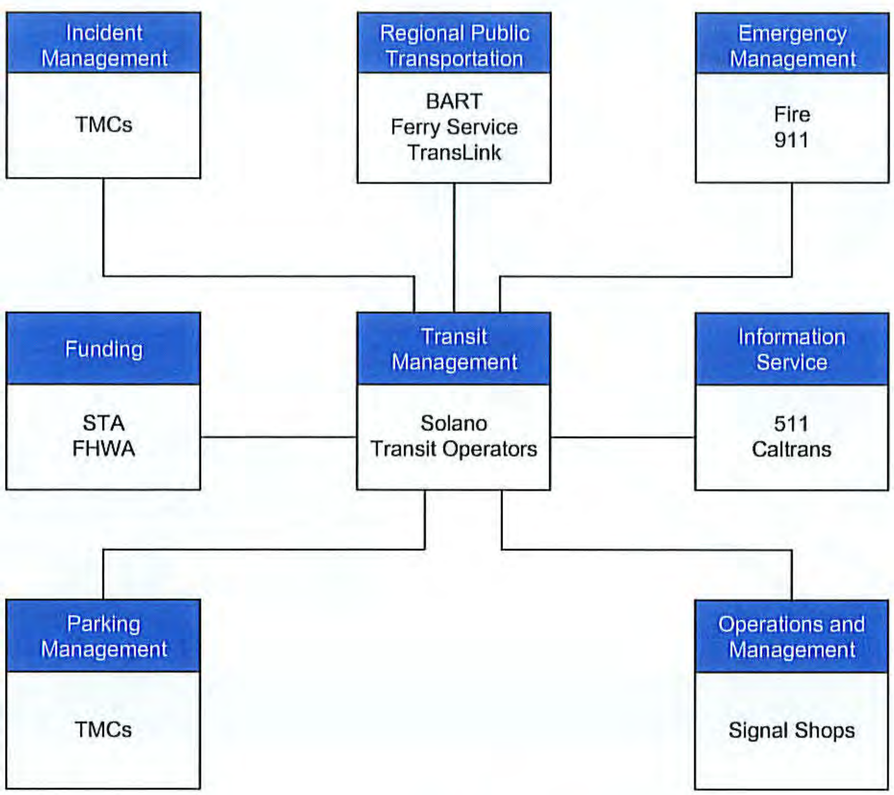


Figure 6-3: Sample Organizational Architecture

The Organizational Architecture is useful to the Solano County Transit ITS stakeholders for the following reasons:

- Groups subsystems by Agency ownership
- Depicts which Agency subsystems are connected to one another
- Provides an initial indication of the hierarchical relationships that exist for the agencies within the County.

Architecture Flow Diagrams

Basically, architecture flows are the primary data/information flows that can exist between subsystems that make up a market package. Because of this, they are arguably the key tools to show conformance with the National ITS Architecture. Through architecture flows, you have a common denominator from which to compare and tailor functionality, systems and projects to install, and people and agencies with whom to talk.

The Architecture Flow diagrams (provided in Appendix C) are useful to the Solano County Transit ITS program's stakeholders for the following reasons:

- Identifies what data/information flows exist between subsystems
- Establishes the initial data flows from which more detailed transit ITS project designs can be based
- Provides key materials/diagrams to establish conformance with the National ITS Architecture.

Bay Area Regional ITS Architecture

In developing the System Architecture for the Program, it was important to recognize that the greatest benefit for most ITS deployments within the County will be realized through integration and coordination with regional ITS deployments in the Bay Area.

To help ensure integration of ITS at a regional scale, MTC recently initiated a project to develop the Bay Area Regional ITS Architecture. This project is currently under development and is expected to finish by May 2003. The agencies within the County have a good working relationship with MTC and the Regional ITS Architecture development. As that project progresses, the agencies will be kept informed in the project activities and meetings.

Standards and Interoperability

ITS standards are specifications that define how system components interconnect and interact within the overall framework of the National ITS Architecture. They specify how different technologies, products and components interconnect and interoperate so that information can be shared automatically. The U.S. DOT Standards Program is working towards fostering the widespread use of interoperable ITS elements by accelerating the development and deployment of ITS Standards. This is essential for achieving the interoperability necessary to function consistently and effectively nationwide. Standards specify how to do things consistently, including the following tasks:

- Enhance safety;
- Speed acceptance & deployment of products and services;
- Enable compatibility, interchangeability, and/or interoperability;
- Adjoining products/systems can work together cooperatively;
- Ability to interconnect devices from different manufacturers interchangeably;
- Same product will operate correctly and consistently;
- Contain cost;
- Assure quality; and
- Minimize confusion avoid reinventing the wheel.

By specifying how systems and components are interconnected, the standards promote interoperability. Interoperability is the ability of ITS to:

- Provide information and services to other systems;
- Accept information and services from other systems; and
- Use the information and services that are exchanged between agencies and sub-system to operate together effectively.

Interoperability will ensure that mobile users can travel across the Bay Area and the Nation and retain the same level of ITS services. There are three types (levels) of ITS interoperability that the Solano County Transit ITS Program needs to be concerned with:

- Technical - the capability for equipment (hardware and software) to communicate effectively (i.e., send and receive information).
- Procedural - common procedures to exchange meaningful information.
- Institutional - administrative and or/contractual agreements between operators and users of the information.

How Can Standards Benefit the Solano County Transit ITS Program?

The County of Solano transit operators are committed to conform with all applicable transit ITS standards that have been or are being developed (see www.its-standards.net) as transit ITS devices are being procured. This provides the following benefits:

- Lower risk of being locked in to proprietary products;
- Provide ability to buy components from different manufacturers;
- Reduce risk of obsolescence;
- Reasonable assurance of quality;
- Lower prices due to increased competition in the market place; and

- Forward and backward compatibility of devices, and interoperability of ITS elements in the region.

7. IMPLEMENTATION PLAN

This chapter presents the overall implementation plan for the Solano Transit Operators ITS Plan over the 20-year horizon.

Implementation Principles

The implementation of Intelligent Transportation System (ITS) projects for the Solano Transit Operators will be carried out by a limited spectrum of agencies within the County, and at a regional level in a complex environment. The success of the program will require multi-agency involvement, consensus, and initiatives to provide a system-integrated approach that benefits all. This is particularly important for those elements that are dependent on one another. For this to occur, many elements need to be properly in place to assure seamless integration. This requires an implementation framework, and this chapter will provide such direction. It should be considered a management tool to assist the Solano Transit Operators in securing future funding and in project planning. The following can provide such a framework, founded on a set of guiding principles for deployment of ITS within the County:

- Projects in the Solano Transit Operators Transit ITS Strategic Plan must be flexible in order to respond to funding opportunities and changing circumstances. A list of prioritized projects (listed later in this chapter) will be used as a management-planning tool to develop future market packages (project bundles) for specific circumstances, using the program vision as a guide. Opportunities for funding the projects are not as obvious as for traditional transportation improvements. Flexibility is key. Complex circumstances will require the Transit Operators to carefully choose projects from the priority list. The highest priority in the list are projects that build a communication infrastructure and projects providing early benefits to the traveler. In some cases, ITS applications may be best implemented as additional elements to conventional improvement projects, or others infrastructure upgrades. The implementation plan will need to be periodically updated.
- The initial deployment of the overall Plan will mainstream ITS into the local planning processes by including ITS as part of capital improvement projects. Doing so in all current and future construction projects allows incremental build out of ITS infrastructure (i.e. backbone communications).
- Integration with major ITS initiatives in the area will be a high priority for future projects. This includes integration with transit operator's activities. Most individual ITS applications will link to other systems requiring a large degree of coordination with other agencies, particularly, Napa County, MTC, TravInfo, and Caltrans District 4.
- Federal funding of ITS projects will be contingent on projects being in conformance with the National Architecture standards. The Plan must adhere to

those conformance standards, including those applicable to the Bay Area, Caltrans and MTC.

- Public Outreach is an integral part of the Solano Transit Operators Transit ITS Plan. The success of the Plan is contingent upon political support, and upon the support of the funding sources. The outreach program will also increase the traveling public's awareness of the benefits of ITS for Transit.
- New standards and federal requirements will be incorporated into all future projects to stay in the forefront of a national program. This includes complying with federal programs and initiatives as well as industry adapted technology standards. Doing so will position the Solano Transit Operators for future federal funding opportunities.
- A Concept of Operations will be developed for any future phase implementation before they are procured. The Concept of Operations will include specific program objectives, roles and responsibilities, and operational strategies and be completed prior to deploying ITS elements for transit.
- An Operation Management Plan is essential to the further advancement of the Plan. Successful ITS applications depend on the approach used to continue operations. A detailed Operation Management Plan will include future staffing, skill requirements, city-wide operational resources and procedures, specific recommended training, an ITS procurement plan, O&M multi-year funding requirements, future integration strategies, equipment needs, and resource allocation and sharing.
- Funding for operation and maintenance of the system will go to support planning, design, implementation, operation and management goals of the Transit Operators. It is anticipated that the SolanoLinks Consortium will ensure that continuing sources of operations and maintenance funding are available prior to beginning projects.
- While the existing transit system currently relies on public funds, the Consortium should continually look for opportunities to partner with the private sector.

Integrated Action Plan

There are a number of actions that should be taken to move the Plan forward. The Initial Phase deployment of the Automated Vehicle Location and Transit Priority Control System will provide a foundation for defining an integrated action plan. This initial deployment supports the general implementation principles and recommendations described earlier. Figure 7-1 shows the concept of streaming ITS into the planning process.

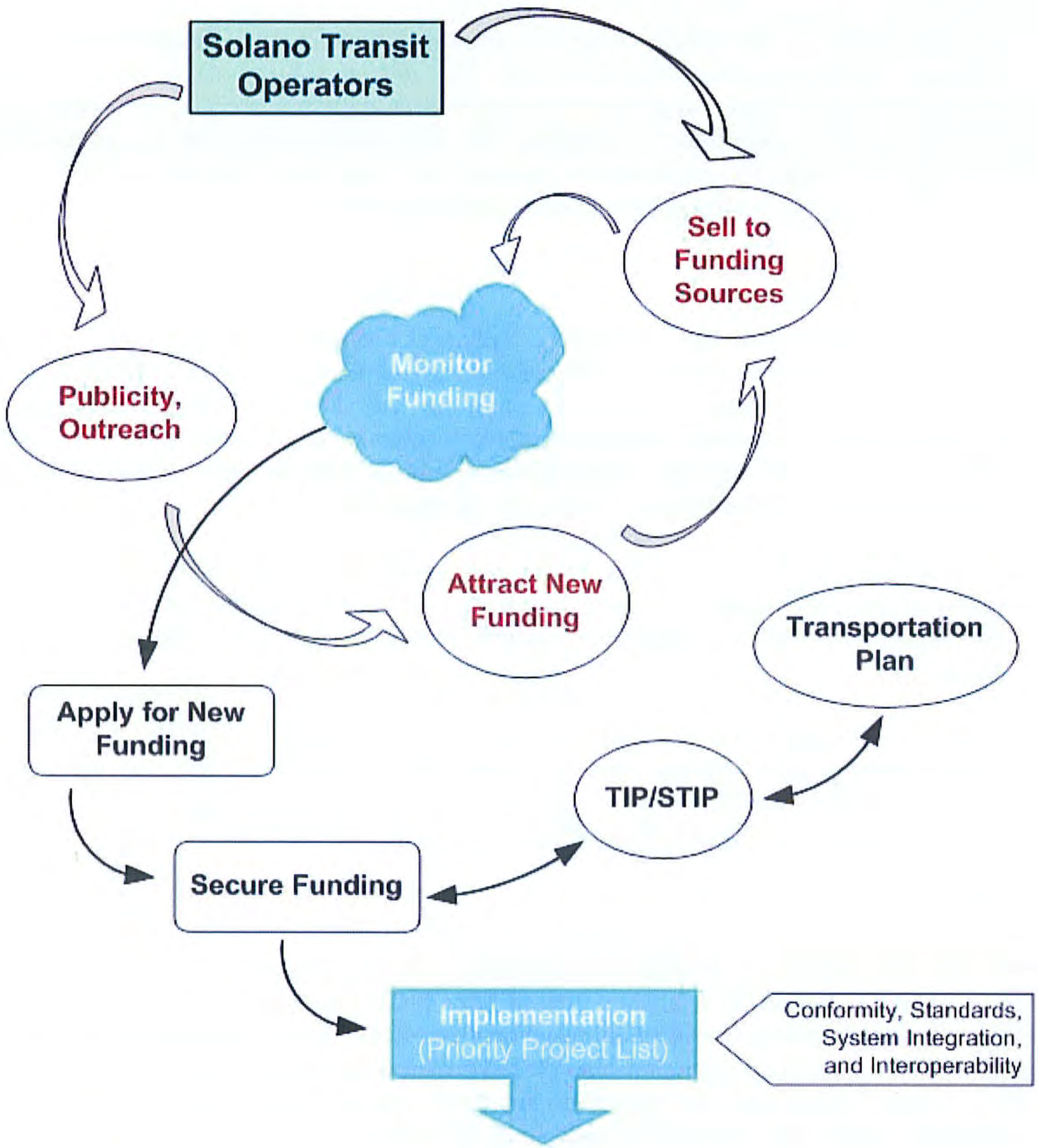


Figure 7-1: Concept of Streamlining ITS into the Planning Process

Initial Phase

The Initial Phase of the Solano Transit Operators ITS Plan is the deployment of an Automated Vehicle Location (AVL) System. This system will provide a framework for the various transit operators to start the process of eventually being on a single integrated platform for transit operations. In addition, this AVL system will start the groundwork for a regional-based communications network for the transit operators which will ultimately include the exchange of valuable transit information.

Communications Network

The communications network for the AVL System is proposed to be an entirely wireless digital mobile network consisting of base stations, antenna towers and field radios. It is envisioned that the dispatch centers will remain the central component for each operator with connections occurring between dispatch centers. By providing an integrated platform for the AVL System, each of the operators will be able to utilize a data exchange network for operating and managing the system.

Each operator will provide the necessary equipment to enable the wireless communications including the towers and base stations. Depending on the frequency used, appropriate licensing from the Federal Communications Commission may be needed.

The mobile communication is necessary to keep communications with transit vehicles equipped with an AVL system when on route, field technicians and other personnel. Mobile computer users and transit operators use wireless communication to contact TMCs, exchange mail, transfer file and data.

Traffic Signal Systems

The ITS Plan provides a process for integrating with the existing traffic signal systems under operation within each of the cities in Solano County. The traffic signal systems disseminate and receive real-time information from field devices including traffic signal controllers, dynamic message signs and closed circuit television cameras. Integrating the AVL system will provide the maximum flexibility for each transit operator in order to balance the transit and automobile needs along the roadways.

Center–to-Center Integration

The ability to integrate with other transit systems or centers is a core requirement within the framework of the Transit ITS Strategic Plan. Standards-based communication protocols will be developed to assist in this goal. This is a critical step to the success of the overall Plan. This is an important feature for the initial deployment of the AVL System. The development of National ITS standards guiding coordination with other agencies will be on-going throughout the life of the Plan.

Website

As part of the initial phases of the Transit ITS Plan, it is envisioned that real-time and static information will be placed on websites for anyone to access it. The Plan envisions the exchange of information between the operators and the public.

Prioritized Project List

The development of the overall Transit ITS strategy for the Solano Transit Operators followed a progression from the general (definition of a vision) to the specific (identification of implementation parameters for individual projects). While each step in the progression built upon previous steps, the Operator's problems, needs, and opportunities served as the overall guiding force. This process is illustrated in the Figure 7.2.

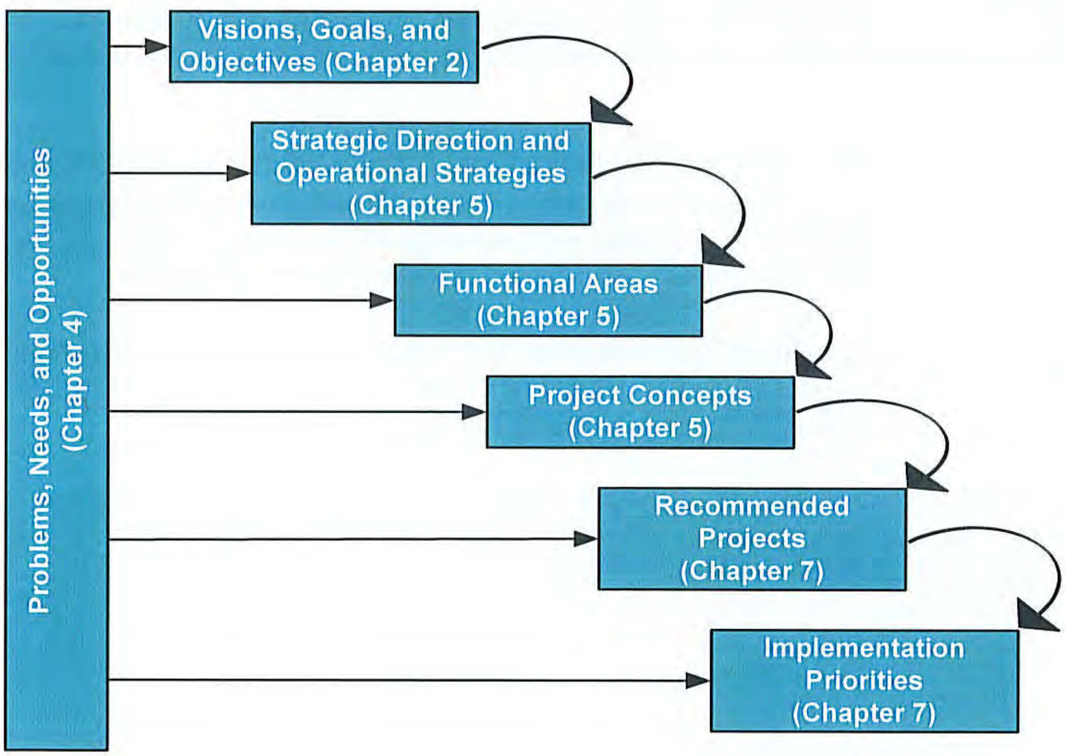


Figure 7.2 - Development Process

The overall Transit ITS Strategic Vision is simply a guide for where the Solano Transit Operators want to go with respect to the deployment of ITS and, to an extent, how they want to get there. The strategic functional areas support and provide additional detail to the vision by defining a strategic direction for the deployment of ITS for transit systems that relates closely to the Transit Operator's identified needs and opportunities. For each of these strategic functional areas, a number of project concepts were identified as a means of going from a functional to an implementation perspective. These project concepts represent loosely defined but distinct projects. With agreement on these concepts, the recommended projects were defined in greater detail, and a subset was identified that reflects the highest priorities for deployment.

The key results and recommendations from each of these steps are summarized in Table 7-1. See also Appendix "D."

The list of prioritized projects has been organized into the various categories as defined by the National ITS Architecture. These categories include the Central Subsystem, the Roadway Subsystem, the Traveler Subsystem, and the Vehicle Subsystem. An additional subsystem was developed specifically for this Plan referred to as the Transit ITS subsystem.

The projects are primarily geared towards expanding the initial deployment of the Transit ITS elements and integrating the operations and management of the different transit operators into a common platform which establishes a cohesive transit network. The integration activities would eventually extend to adjacent counties and ultimately around the Bay Area.

A secondary focus of the prioritized projects includes the deployment of various traveler information devices at key locations within the region. These information devices will serve to inform the users of the system with valuable information so they can make informed decisions about their travel plans and increase their level of confidence.

The primary focus of the Transit ITS subsystem is to keep the Plan in step with changing technology in the area of ITS and to maintain a sense of cooperation between transit operators in terms of information sharing and maintenance.

The costs indicated are order of magnitude estimates of the probable cost to design and implement each specific project. This includes all related design costs and the procurement of specific hardware and software.

Table 7-1: Priority Projects Listing

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Upgrade Fairfield Dispatch	This includes transit priority system upgrades, hardware and software, central control to accommodate TPCS. Upgrade AVLS hardware/software/license to accommodate additional buses, paratransit, mapping, displays, website	FST Fairfield Suisun City STA/Solano Links MTC Caltrans FTA FHWA	0-5	300	30	Increased system utilization, improved benefit/cost ratio, and increased system efficiency. Provides a foundation to continue development of Transit ITS in Solano County. Provides a potential centralized network for managing Transit in Solano County.
Central Elements	Upgrade Vallejo Dispatch	This includes transit priority system upgrades, hardware and software, central control to accommodate TPCS. Upgrade AVLS hardware/software/license to accommodate additional buses, paratransit, mapping, displays, website	Vallejo Transit Vallejo STA/Solano Links MTC Caltrans FTA FHWA	0-5	300	30	Increased system utilization, improved benefit-cost ratio, provides system efficiency. Provide foundation to continue development of Transit ITS in Solano County. Provide centralized control for managing transit in Solano County

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Upgrade Vacaville Dispatch	This includes transit priority system upgrades. Upgrade AVLS hardware/software to accommodate additional buses, paratransit, mapping, displays, website	Vacaville City Coach Vacaville STA MTC Caltrans FTA, FHWA	0-5	200	20	Increased system utilization, improved benefit-cost ratio, provides system efficiency. Provide foundation to continue development of Transit ITS in Solano County.
Central Elements	Integrate Vallejo Dispatch centers (fixed-route, paratransit, ferry)	This primarily consists of real-time information sharing between different dispatch centers in Vallejo and developing interface requirements.	Vallejo Transit Vallejo RunAbout Vallejo Ferry Vallejo STA/Solano Links MTC Caltrans FTA FHWA	10-15	150	15	Increased system utilization and improved coordination between transit functions leading to improved system efficiency.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Upgrade Fairfield TMC for Transit Elements	This includes incorporating a Graphical User Interface (GUI) for transit elements into a City-built ATMS. Incorporate interface with dispatch for TPCS and AVLS with Transit only GUI. This include communication link to Fairfield Dispatch Center.	FST Fairfield Suisun City STA/Solano Links MTC Caltrans FTA FHWA	10-15	200	20	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.
Central Elements	Upgrade Vacaville TMC for Transit Elements	This includes incorporating GUI for transit elements into City-built ATMS. Incorporate interface with dispatch for TPCS and AVLS with Transit only GUI. This include communication link to Vacaville Dispatch Center.	Vacaville City Coach Vacaville STA/Solano Links MTC Caltrans FTA FHWA	15-20	200	20	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Upgrade Vallejo TMC for Transit Elements	This includes incorporating GUI for transit elements into City-built ATMS. Incorporate interface with dispatch for TPCS and AVLS with Transit only GUI. This include communication link to Vallejo Dispatch Centers	Vallejo TransitVallejo STA/Solano LinksMTCCal transFTAFH WA	10-20	200	20	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.
Central Elements	Integrate Dixon, Benicia, Rio Vista, Suisun into County-wide AVLS/TPCS system	Design, build and integrate workstations for Dixon, Benicia, Rio Vista, Suisun and other remote locations. Incorporate AVLS/TPCS central elements including GUI and other interfaces. This includes each city's connection to a main dispatch center.	Dixon Benicia Rio Vista Suisun City STA/Solano Links MTC Caltrans FTA FHWA	10-20	300	10	Increased system utilization, improved benefit/cost ratio, and improved system efficiency. Provides a foundation to continue development of Transit ITS in Solano County.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Integrate with regional TMCs	Integrate SolanoLink Transit Information System with regional TMCs, including TravInfo, Caltrans, adjacent counties (Napa, Yolo, Sacramento, Contra Costa)	STA/Solano Links MTC Caltrans FTA FHWA	5-10	500	50	Increased system utilization, improved benefit/cost ratio, and improved system efficiency. Provides a foundation to continue development of Transit ITS in Solano County and neighboring counties.
Central Elements	Center-to-Center (C2C) integration between TMCs and dispatch centers	This includes inter-city communication links between the main dispatch centers to share transit information.	STA/Solano Links MTC Caltrans FTA FHWA	5-10	500	40	Increased system utilization, improved benefit/cost ratio, and improved system efficiency. Provides a foundation to continue development of Transit ITS in Solano County and neighboring counties.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Incorporate National Standards County-wide	Upgrade TMC/Dispatch center software/hardware system to accommodate latest development standards for inter-operability and uniform county standards. This includes the latest NTCIP standards and conformity to national system architecture.	STA/Solano Links MTC Caltrans FTA FHWA	every 3 years	480	10	Improved interoperability of different Transit ITS elements. Provides a more solid foundation to expand the deployment of Transit ITS in Solano County and neighboring counties.
Central Elements	Integrate with MTC TransLink System	Integrate SolanoLink Transit Information System with MTC's TransLink System for an integrated regionwide transit network.	STA/Solano Links MTC FTA Caltrans	5-10	500	25	Increased system utilization, improved benefit-cost ratio, provides system efficiency through valuable information exchange. Provide foundation to continue development of Transit ITS in Solano County.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Central Elements	Integrate Vallejo Ferry GPS equipment with Transit Dispatch Centers	This primarily consists of real-time information sharing between the Vallejo Ferry System and the other dispatch centers in Solano County.	STA/Solano Links MTC FTA	0-5	300	20	Improved transit coordination and dispatch efficiency. Tool for gathering real-time information for all transit operators. Provide foundation to continue development of Transit ITS in Solano County.
Roadway Elements	Expand Transit Priority components in Fairfield	This consists of expanding and/or enhancing the planned and existing transit priority systems in Fairfield.	City of Fairfield BAAQMDFT AFHWA	0-5	1000	50	Improved system performance and efficiency and improved benefit/cost ratio. Provides a foundation to continue development of Transit ITS in Solano County.
Roadway Elements	Expand Transit Priority components in Vallejo	This consists of expanding and/or enhancing the planned and existing transit priority systems in Fairfield.	City of Vallejo BAAQMD FTA	0-5	1000	50	Improved system performance and efficiency and improved benefit/cost ratio. Provides a foundation to continue development of Transit ITS in Solano County.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Roadway Elements	Install Transit Priority components in Vacaville	This consists of installing a transit priority system in Vacaville.	City of Vacaville BAAQMD FTA FHWA	0-5	750	35	Improved system performance and efficiency and improved benefit/cost ratio. Provides a foundation to continue development of Transit ITS in Solano County.
Roadway Elements	Design and Build Communication Infrastructure in phases	This includes the design and installation (in phases) of a wireless communications system between vehicles and dispatch.	STA/Solano Links MTC FTA FHWA	0-5	2000	60	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.
Roadway Elements	Upgrade Controller hardware/software to include Transit Signal Priority	This consists of procuring new hardware/software with advanced transit priority algorithms for improving transit vehicle schedule adherence while minimizing impacts to automobile traffic.	STA/Solano Links MTC FTA FHWA	0-5	500	10	Improved system performance and efficiency. Provides a foundation to continue development of Transit ITS in Solano County.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Traveler Elements	Install Parking Guidance System (PGS) at Park & Ride Lots, Intermodal Train Station, Ferry Terminal	This consists of guidance systems to inform users of park-and-ride lots and other transit facilities of the status of usage including available spaces, transit vehicle arrivals/departures and other transportation conditions.	STA/Solano Links MTC FTA FHWA	5-10	500	20	Increased system utilization with more accurate information to system users.
Traveler Elements	Implement transit stop information signs in phases	This consists of a system that will provide real-time information to transit users of the transit system at transit stops.	STA/Solano Links MTC FTA FHWA	0-5	350	15	Increased system utilization with more accurate information to system users.
Traveler Elements	Implement kiosks at major activity centers in phases	This consists of a system that will provide real-time information to users of the transit system at major activity centers.	STA/Solano Links MTC FTA FHWA	5-10	250	20	Increased system utilization with more accurate information to system users.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Traveler Elements	Enhance Intermodal Transfer Station with ITS elements	This includes security and surveillance, communication hub points, and emergency coordination points.	STA/Solano Links MTC FTA FHWA	0-5	250	10	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.
Traveler Elements	Design and implement Solano County Transit Operators website	This includes route-planning and real-time AVL info, video feed, messages, incidents, ride-share	STA/Solano Links MTC FTA FHWA	0-5	150	5	Increased system utilization with more accurate information to system users.
Traveler Elements	Develop interface with TravInfo and other traveler information websites	This consists of an integrated link with TravInfo and other potential sites for the exchange of real-time information for dissemination to the users of the transit system.	STA/Solano Links MTC FTA FHWA Caltrans	5-10	500	25	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Traveler Elements	Develop interface with Personalized Traveler Information (PTI) system provider	This consists of an integrated link with providers of Personalized Traveler Information Systems for the exchange of real-time information for dissemination to the users of the transit system.	STA/Solano Links MTC FTA FHWA	5-10	300	5	Increased system utilization with more accurate information to system users.
Traveler Elements	Develop interface with other media providers	This will provide an interface with Cable TV, Radio Stations, and other media groups.	STA/Solano Links MTC FTA FHWA	0-5	100	5	Increased system utilization with more accurate information to system users.
Vehicle Elements	Expand AVL system to all regional fixed-route transit vehicles	This consists of expanding the base AVL System to include the other transit operators *not included in the initial phases* and all of their transit vehicle fleet for a regional transit information system.	STA/Solano Links MTC BAAQMD FTA FHWA	5-10	2000	50	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Vehicle Elements	Expand AVL system to all other fixed-route transit vehicles	This consists of expanding the base AVL System to include other transit operators outside of Solano County and their transit vehicle fleet for a Bay Area transit information system.	STA/Solano Links MTC BAAQMD FTA FHWA	5-10	1000	25	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.
Vehicle Elements	Expand AVL system to all paratransit vehicles	This consists of expanding the base AVL System to include paratransit vehicles.	STA/Solano Links MTC BAAQMD FTA FHWA	5-10	500	15	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.
Vehicle Elements	Implement Smart Bus features for all buses in Solano County in phases	Implement/deploy Smart Buses which could include features such as automatic announcements, safety systems, intelligent cruise-control, near-object detection, back-up warning, lane sensors, collision avoidance, smart card reader, and may day alerts.	STA/Solano Links MTC BAAQMD FTA FHWA	10-20 years	2000	50	Increased system utilization and improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Vehicle Elements	Implement Advanced Transit Fleet Maintenance Administration	Deploy an advanced maintenance administration system that would link all of the transit vehicle's on-board components.	STA/Solano Links FTA FHWA	0-5	300	25	Improved maintenance process resulting in savings due to preventative maintenance.
Transit ITS Planning	Develop Operations and Maintenance Transit ITS management plan	This would consist of developing an O&M plan for the overall transit system network which would utilize the ITS components.	STA/Solano Links FTA FHWA	0-5	200		Improved maintenance process resulting in savings due to preventative maintenance.
Transit ITS Planning	Update Operations and Maintenance Transit ITS management Plan	This would consist of updating the O&M plan to account for changes in ITS technology.	STA/Solano Links FTA FHWA	every 3 years	100		Improved maintenance process resulting in savings due to preventative maintenance.
Transit ITS Planning	Update Solano County Transit ITS Plan	Incorporate into the updates of the STA Comprehensive Transportation Plan	STA/Solano Links MTC FTA FHWA	every 3 years	200		Improved coordination amongst transit operators.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Transit ITS Planning	Evaluation Studies of Transit ITS elements for transit system efficiency and performance	Publicize and demonstrate benefit, secure funding for future phases. This includes before and after studies, etc.	STA/Solano Links MTC FTA FHWA	every 3 years	100		Improved system efficiency by recognizing and planning for the deployment of new technologies for transit.
Transit ITS Planning	Develop Transit ITS data mart/ data warehouse	Develop a distributed data warehouse for transit operators to deposit and gather information for later retrieval.	STA/Solano Links MTC FTA FHWA	0-5	50	10	Improved coordination between transportation and transit staff and related functions leading to improved overall system efficiency through the exchange of reliable information.
Transit ITS Planning	Conduct Transit ITS technology assessment and evaluation	Conduct a technology assessment of the latest and greatest advancements in technologies for the use of ITS technologies in transit.	STA/Solano Links MTC FTA FHWA	every 5 years	80		Improved system efficiency by recognizing and planning for the deployment of new technologies for transit.

Table 7.1 – Priority Projects Listing (continued)

Project Type	Project Title	Project Description	Potential Participants	Time frame (years)	Implement. Cost (100K)	Annual O&M Costs (100K)	Expected Benefits
Transit ITS Planning	Develop Public Outreach and Awareness Plan	Coordinate with STA current program. Publicize ITS benefits; secure additional funding for future phases. Showcase in major regional and national ITS conferences and/or forums. Develop brochures.	STA/Solano Links MTC FTA FHWA	every year	50		Improved relations with the users of the transit system resulting in increased system usage.

Funding

Funding is a critical factor in the success of any ITS Strategic Plan initiative. Regional organizations require funding support for:

- Program Development – Capital development costs for new programs and project implementation;
- Ongoing Operations – Support for operations personnel and equipment upgrades for existing initiatives; and
- Administrative Functions – Staff time, materials, and overhead for organizational support function.

Operations programs require ongoing funding support over an indefinite time period. Maintaining consistent funding support is a challenge for Solano County Transit Operators in the face of competing needs and limited sources for personnel and operations support.

Funding Issues and Lessons Learned

Funding for Ongoing Operations – Most of the organizations developing similar programs struggle with finding sources of funding for ongoing operations and staff support. The Federal grants under which many were started do not support long-term operations. Consequently, regional operating agencies find other sources of funding. Operations projects often have difficulty competing for funding with other local and state needs. Federal government agencies are now trying to tie the future grant application to some kind of operational funding to assure program continuity.

Federal Congestion Mitigation and Air Quality (CMAQ) funds are frequently applied to operations projects, but are not available in all areas and are limited in their ability to support operations on an ongoing basis. Some agencies also apply Surface Transportation Program (STP) funds to operations programs. However, use of these funds often faces competition from roadway development and maintenance projects.

Pooled Funding – Most of the partnerships (such as STP) pool funding to provide matches to Federal grants. However, TRANSCOM, in New Jersey, and TranStar, in Houston, also have procedures for pooling funding to support ongoing operations and personnel. Thus potholing funds maximizes the amount of funding to use for implementation.

TRANSCOM requires member dues on a sliding scale from 0 to 15 2/3 percent of its total operating budget. This budget supports its 29 staff members and upkeep of the Operations Information Center. Funding responsibilities based on relative ability to pay are determined when an agency joins TRANSCOM.

TranStar participants share costs for facility maintenance and support of a seven-person administrative staff through a formula based on building occupancy (office space and total square footage), computer and telecommunications equipment usage, and operating time (system support requirements). The organization also maintains a pooled fund, based on predetermined ratios, to provide matches to Federal funds.

Dedicated Funding – Dedicated funding is the most stable source of funding for regional operations programs.

MTC, in the Bay Area, receives dedicated funding for its freeway service patrol program, part of the Service Authority for Freeways and Expressways (SAFE) through a state-legislated $1 vehicle registration fee vehicle per year.

Vancouver TransLink can raise revenue through taxes and tolls. All revenues are dedicated to TransLink programs, which are determined through a comprehensive planning process. TransLink's budget includes support for administration and operations programs. TransLink found in public opinion surveys that residents were not opposed to new taxes to fund specific transportation service improvements, including transit service enhancements.

Integration with Traditional Planning Processes – Two of the regions experienced problems with receiving money through Federal grants due to lack of integration with traditional approval processes for transportation funding. Traditional funding processes require projects to be included in approved Regional Transportation Improvement Plans. The process is based on strategic planning and involves political officials, the public, and transportation professionals. These processes help to develop constituent support for programs and ensure that they are compatible with other transportation activities in the region. The two regions experiencing this problem felt that programs developed outside of this process have difficulty maintaining adequate constituency support after the grant funding expires. They also noted a disconnect between the programs and other transportation activities in the region.

SOLANO COUNTY TRANSIT
ITS STRATEGIC PLAN

Appendix A
Technology Summary Report

Solano County Transit ITS Plan

Automated Vehicle Location System and Transit Priority Control System

TECHNOLOGY SUMMARY REPORT

FINAL DRAFT

(for input into the Transit ITS Strategic Plan)

Prepared for

FAIRFIELD

by

DKS Associates

December 2002

Table of Contents

INTRODUCTION AND BACKGROUND

This report discusses the various technologies that have been used for Automated Vehicle Location Systems (AVLS). It provides detail on each of the technologies and discusses the specific applications. In addition, it describes the various components that are placed within a transit vehicle and the related elements that form an overall AVL system.

VEHICLE POSITIONING SYSTEMS

Various technologies for vehicle positioning systems have been utilized over the years to determine the positions of mobile vehicles. Each technology has its strengths, weaknesses, and unique operational characteristics. In many cases, two or more complimentary technologies have been applied for the same application in order to overcome or minimize some of the limitations of the individual technologies. For transit applications, the technoligies that have been used for vehicle positioning and location include the following:

- Signposts
- Loran-C
- Dead reckoning
- Terrestrial-based Triangulation, and
- Global Positioning System (GPS).

These are only the technologies that form the positioning function of an overall AVL System. Some of these technoligies have been used in combinations to form a complete system. The fundamentals of each of these technologies are discussed in the following sections along with their advantages, disadvantages, and alternative implementation approaches.

Signposts

Signpost-based vehicle tracking employs a network of either active or passive signposts strategically placed throughout the geographic area where vehicle tracking is required. In a transit application, signposts would be located along the routes to be followed by the vehicles. As a vehicle passes a signpost, the passage is communicated to the dispatch center, where the vehicle position is then updated from its last known location and its on-time performance is re-calculated.

The primary limitations of this technology are that each vehicle's route must be known in advance and each vehicle's location is only known on a sporadic basis, as each vehicle passes a signpost. At all other times, vehicle positions can only be estimated, based on the last signpost passed and the known schedule. This technology, therefore, is only suitable for fixed-route applications and it is not usefull for paratransit or other variable-route services.

The signposts can either be active or passive. With active signposts, the signpost broadcasts a signal that is detected by a passing vehicle equipped with a suitable receiver. Passive signposts rely on a signal transmitted from the passing vehicle to interrogate the signpost for its signpost identification. In most applications, the occurrence of a signpost passage is reported to central dispatch via the vehicle's radio equipment. Some systems, however, are designed to have each signpost report directly to central dispatch via radio or land-line communications.

In signpost systems, the frequency with which a vehicle's location is reported depends on how often each vehicle passes a signpost. The only ways to improve the frequency of the position reports is to optimize the placement of the signposts or to install more signposts. Increasing the number of signposts, however, directly increases project costs. This also makes the network of signposts more difficult and costly to maintain.

Another inherent disadvantage of signpost technology is that with the signposts scattered throughout the territory, they are subject to vandalism and theft.

Overall the performance of signpost systems has been poor and many transit agencies have abandoned their installed systems. Also, customer and vendor support for this technology is rapidly decreasing and few if any improvements are being made to this technology. Any signpost-based system installed today could lose the vendor's support in a very short time as the vendor is forced to switch to more viable and versatile location technologies.

Loran-C

Loran-C has been used for land-based, marine, and aircraft navigation over the last 20-30 years. This system is based on a network of transmitters that transmit or relay timing signals. Vehicle locations are determined by comparing the timing signals received from different transmitters and triangulating a position. The positional accuracy is limited to approximately 250-300 feet and the signals are subject to atmospheric distortion, which can further degrade the positional accuracy.

Loran-C is operated and maintained by the U.S. Government. Now that GPS is fully operational and proven it is expected that the government will discontinue maintenance of the Loran-C systems. Some of the more remote Loran-C transmitter sites have already been decommissioned and the entire Loran-C network will likely be discontinued in the near future.

Dead Reckoning

Dead reckoning employs one or more sensors on-board the vehicle to determine a vehicle's motion without reference to any outside signal. Essentially it is a means of inertial navigation. Odometers, gyroscopes, and compasses are the most commen sensors used for dead reckoning. Odometers can either be employed alone, in pairs, or in conjunction with gyroscopes or compasses. When an odometer is used alone, it only enables the distance travelled by a vehicle to be measured. Therefore, in a transit application, the use of an odometer by itself can only provide the distance travelled along a fixed-route. However, even in this case, the usefulness of an odometer alone is quite limited because of the inaccuracies inherent with odometers.

Typically, odometer based tracking has an inaccuracy of 2-4%. At this rate, errors quickly accumulate and soon the reported position is far from the vehicle's actual position.

To partially overcome the inherent inaccuracy of odometer tracking, other sensors or indications are used in conjunction with the odometers. These other sensors or indicators are typically gyroscopes, compasses, or, in the case of many European systems, door indications. The basic purpose of these additional sensors is to provide definite reference points along the route so that the odometer only has to measure distances between known reference points. This allows for periodic corrections of the odometer measurements and thereby reduces the magnitude of the odometer errors.

When a gyroscope or a compass is used, its purpose is to determine both the magnitude and direction of a vehicle's turns. This information is compared with the known turns in a vehicle's route in order to determine where along the route the vehicle is located. Between these known reference points, the odometer is used to measure distance. The vehicle is assumed to be on-route until an incorrect turn is detected or until a planned turn is not detected.

Door indications are used in conjunction with odometer readings in many European systems. In these systems, the basic philosophy is to track vehicles from one bus stop to the next. Therefore, the route is defined in terms of distances to the next stop and the tracking is done by measuring odometer distances to the next expected bus stop. In cases where a bus stop is skipped, the driver must indicate that the bus stop was passed. This approach is also limited to on-route vehicles. Once a vehicle deviates from the route, its distance travelled is known but its direction of travel is unknown.

One other dead reckoning approach is to install a pair of odometer sensors, one on each of the front wheels. In this way, the distance travelled by each wheel can be measured and differences in the wheel rotations can be used to determine turns. This approach is known as the differential odometer method.

Dead reckoning technology requires advance knowledge of each vehicle's planned route. Each vehicle's route also must be downloaded to the vehicles. This downloading is typically done via radio transmissions, smart cards, or by plugging a portable PC into each vehicle unit before each vehicle leaves the yard at the beginning of a service day.

All of the above dead reckoning approaches are subject to errors which limit the applicability and accuracy of this technology. The overall reliability of the odometer devices is also an important concern. The requirement for comparison with a known fixed-route in order to compensate for the intrinsic inaccuracies limits the use of this technology to fixed-route vehicles. This technology is not suitable for use with paratransit or flexible route deviation-type services. As in the case of signpost technology, customer and vendor support for dead-reckoning systems is rapidly decreasing and few, if any, improvements are being made to this technology.

Terrestrial-Based Radio Triangulation

A number of commercial vehicle location systems are currently being established in major metropolitan areas throughout the United States. These systems are generally radio-based triangulation systems that locate a given vehicle by commanding a vehicle to transmit a locating signal and then triangulating the vehicle's location by means of receiver sites located throughout the metropolitan area. These systems can provide accuracies to a few hundred feet but they are not intended to support frequent vehicle position reports from each vehicle. Their purpose is to locate a selected vehicle on-demand on an infrequent basis. Typically, each fleet operator is provided with a PC-based system that can be used to request a vehicle's location. Once the vehicle is located via the triangulation method explained above, the vehicle's location is reported to the requesting user. The user is typically charged a base fee plus a per usage charge. The per usage charges would make it cost prohibitive to request locations for each vehicle in a large fleet on a frequent basis, such as once every 1-3 minutes, as is typical for modem transit vehicle location systems.

Global Positioning System (GPS)

GPS is based on a configuration of 24 satellites operating in non-geosynchronous orbits of 11,000 miles above the earth. These satellites provide 24 hour-a-day, 7 day-a-week positioning signals to every point on the earths surface. This system was developed by the Department of Defense and it is available to anyone who wants to use it, at no cost. This system is capable of providing positional accuracies of 5-10 meters when it is operating in the Acquisition mode. However, the system can be operated in the Selective Availability mode for national security reasons. The Selective Availability mode introduces random errors that limit positional accuracy to approximately 100 meters (328 feet), unless a special military-only Clear Acquisition mode receiver is used. However, for non-military use, it is also possible to greatly reduce the errors introduced by Selective Availability mode by using a variation of GPS called "Differential GPS (DGPS)."

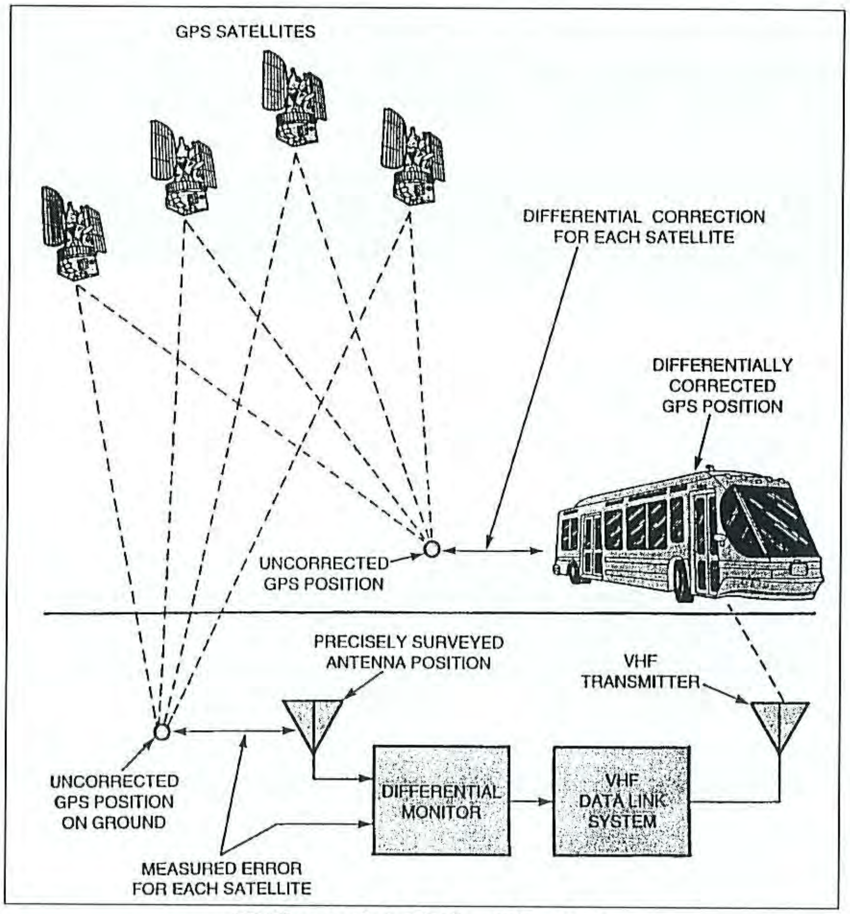
The government removed the use of Selective Availability in May of 2000, making the full accuracy available to all users without the use of differential GPS.

The basic operation of GPS is that each of the 24 satellites transmits a very accurate time signal that is synchronized to an atomic clock reference. Each satellite transmits a coded signal that identifies both the unique identity of the satellite and the time that the signal was transmitted (times are accurate to 1 microsecond). A GPS receiver, located in each vehicle, must then determine what satellite signals it is receiving and the exact time that each signal was received. This information is used in conjunction with data about each satellite's orbit (ephemeris) to determine the distance from each satellite. The results of at least three satellite fixes are then used to triangulate the position of the receiver and thus the vehicle. In cases where more than three satellites are visible, the GPS receiver determines the best satellites to use for an accurate position calculation.

GPS works best when there is clear, unobstructed visibility of the sky, but GPS will also work under more restricted conditions such as in urban canyons in dense metropolitan areas. In the most severe cases, such as downtown Manhattan in New York City, tests with New York City Transit have shown that at a minimum, position fixes can typically be obtained at street intersections. Most cities, however, do not have the density of skyscrapers found in Manhattan, and therefore, GPS-based tracking is suitable even in downtown areas of most cities. Momentary obstructions can occur; however, the GPS equipment is designed to handle these situations and to quickly re-acquire the satellite signals when they are again visible.

GPS-based tracking is completely autonomous. It does not require fixed starting points or reference points along a vehicle's route. Therefore, it is suitable for use in any kind of transit application including fixed-route, route deviation, and demand-responsive paratransit services.

As mentioned above, the standard accuracy available to non-military users of GPS is 100 meters. However, Differential GPS is a simple and inexpensive way to achieve positional accuracies of 5-10 meters, regardless of natural ionospheric and government-induced errors in the satellite signals (see figure 1). This method requires the addition of a special GPS reference receiver that is fixed at a precisely known location. Instead of using the satellite timing signals to calculate an unknown position, the signals are used to calculate timing errors in satellite signals based on the known location of the GPS reference receiver. Essentially, the fixed receiver is used to solve the GPS equations in reverse and thus determine the value of the timing errors for each visible satellite.



Differential GPS – Figure 1

The timing errors for each satellite in view of the fixed receiver are periodically calculated and then broadcast, via radio, to each mobile Differential GPS receiver. The mobile receivers then adjust each satellite's received signal by its current error factor. In this way, virtually all the errors in the satellite signals can be removed and the accuracy of the calculated position is maximized.

Differential GPS, because of its inherent advantages over the other vehicle location technologies, is rapidly gaining acceptance by both users and vendors. Equipment prices are decreasing significantly while technological improvements in the products are continuing to be introduced. For all intents and purposes, Differential GPS is now the de-facto standard vehicle location technology for mobile land applications.

Combinations of Positioning Technologies

As mentioned earlier, it is also possible to utilize more than one AVL technology concurrently to correct for the limitations of a technology in the particular environment in which it is being used. Typically, dead reckoning technology is used to supplement other AVL technologies such as signposts or GPS.

When signposts are employed, each vehicle's position is only known accurately when the vehicle is at a signpost. At all other times, each vehicle's location can only be estimated. This estimating can either be done based on a known route and schedule or based on dead reckoning sensors such as odometers. Typically, a simple distance measurement from the last signpost is utilized to estimate the distance traveled along the defined route between adjacent signposts.

In the case of GPS-based systems, dead reckoning sensors are sometimes used for tracking vehicles when GPS tracking is not possible because of local obstructions. These obstructions could include long tunnels or other overhead structures, severe urban canyon conditions, or severe natural canyon or dense foliage conditions. The decision on whether or not supplemental dead reckoning devices are warranted, in a particular situation where GPS is the primary AVL technology, is largely dependent on how often and how long obstructions of the GPS signals are expected, and the ramifications of such signal obstructions.

VEHICLE EQUIPMENT TECHNOLOGIES

Vehicle Control Heads

The vehicle control heads (VCH) commonly used in modem transit applications are relatively simple, low-cost devices. The VCH normally have a two-to-four line alphanumeric display, and from 10 to 30 function and numeric entry keys. Also, a covert microphone is often integrated into the VCH for audio monitoring when an emergency alarm is active.

The alphanumeric displays typically allow from 20 to 80 characters to be displayed at once. A display scrolling capability is provided to view longer messages and to view previously transmitted messages. The displays are commonly based on liquid crystal display technology. Low glare glass and Bus Operator adjustable backlighting are also provided to allow the displays to be read over the full range of lighting conditions from bright sunlight to darkness.

The displays are used to show data messages transmitted from the Radio Operator/Dispatcher to the Bus Operators, canned data messages that the Bus Operator can transmit to the Radio Operator/Dispatcher, date/time, and schedule/route adherence information.

Messages transmitted by the Radio Operator/Dispatcher may include routine canned messages and free-form messages entered by the Radio Operator/Dispatcher, such as reroute instructions. The keypads typically consist of a set of keys required by the specific computer aided dispatching (CAD) system being, used and a set of user-definable keys and numeric entry keys. Full alphanumeric entry capability is typically not needed or provided. The typical design goal is to provide the Bus Operators with the keys required to indicate the most common conditions with a minimum number of keystrokes. To increase the number of functions that can be performed with a fixed number of keys, many keys are often assigned as dual-function keys.

The specific keys provided on each VCH can usually be customized via software and changeable key legends for the specific type of service to be performed by each vehicle. In this way, maintenance vehicles can be provided with VCH keys to indicate the status of the current repair/service assignment while the fixed-route vehicles have the VCH keys required for fixed-route service, and the paratransit vehicles have VCH keys required for paratransit service.

Intelligent Vehicle Control Units

Intelligent Vehicle Control Units (IVCU) are used on-board transit vehicles to handle the various communications and control tasks associated with interfacing the vehicle subsystems and sensors to the communications network. These units are microprocessor based devices specifically designed to operate in harsh environments, which may include high levels of vibration, dust, moisture, electromagnetic noise, and mechanical shock, as well as power source fluctuations.

These units control the radio, receive and process inputs from the vehicle control head, store and control the messages being displayed on the vehicle control head and transmit, receive and store data for other on-board devices. If AVL and on-board schedule adherence monitoring is implemented on a vehicle, the IVCU would be responsible for downloading and storing the schedule and route information from the central system and then calculating the vehicle's schedule and route adherence based on the schedule data and the real-time data received from the AVL sensors. The IVCU would also be responsible for displaying the vehicle's schedule/route adherence status on the vehicle control head and for notifying the central CAD/AVL system of any schedule/route deviations beyond defined thresholds.

The IVCU would also be responsible for storing and transmitting data received from other on-board devices that have been installed and interfaced to the IVCU, such as automatic passenger counters, fare boxes, wheelchair lifts, door sensors, and engine monitoring sensors. Audio and visual passenger information subsystems can be interfaced to the IVCU so that vehicle location data can be used to automatically trigger sign changes and audio announcements along the vehicle's route.

Vehicle Area Networks

Interfacing to a wide variety of on-board electronic devices and sensors can be a very difficult and costly task, particularly when each device is manufactured by a different vendor and diverse communications media and protocols are utilized. In order to help simplify the interfacing task, vehicle area network (VAN) standards have been proposed to provide a common hardware and communications protocol design that all equipment vendors could use when communicating with other on-board devices and subsystems.

A vehicle area network standard, the German VDV standard, is well established and is supported by equipment suppliers in Europe. The possibility of adopting this standard for use in the United States has been considered by various transit agencies and a FTA/ITS America Advanced Public Transportation System (APTS) working group known as the Bus/VAN Technical Working Group. The conclusion of this working group was that the German VDV standard was inappropriate or inadequate for use in the United States. Although no perfect approach nor single standard was identified by this group, an existing Society of Automotive Engineers (SAE) standard was identified that could serve as a basis for developing a vehicle network standard suitable for public transit vehicles. This SAE standard is J1708, *Serial Data Communications between Microcomputers in Heavy-Duty Vehicle Applications*. This standard essentially defines the hardware configuration while a companion SAE standard (J1587) defines the conununications protocol and data packet assignments.

The J1587 standard has now been updated to include the message ID assignments required for transit vehicles. Although some J1708/JI587 details still need to be resolved, especially as far as hardware is concerned, many equipment vendors are now developing J1708/JI587 compliant interfaces for their devices and some new vehicle procurements are requiring J1708 VAN wiring throughout the vehicles. Though not yet common, the J1708/J1587 standards are gaining support as the preferred standards for transit applications in North America.

On-Board Data Storage & Retrieval

A critical design issue when an extensive amount of data is to be transferred between transit vehicles and central dispatch is how the data can be transferred in the most efficient and cost-effective manner.

Data is normally transmitted via radio communications, provided there is adequate radio system capacity for the data load and provided the radio reception is suitable for reliable data communications. In cases where data is not required to be transmitted in real-time, other means of on-board storage are needed so that the data can either be transmitted during non-peak periods or transferred via another mechanism.

The general, non real-time approaches that have been utilized for transferring data to/from transit velicles include

(1) transferring data via radio during non-peak periods,
(2) transferring data via removable media, and
(3) transferring data by physical or infrared probes.

In the first approach, the data that does not have to be transmitted from the vehicle in realtime is stored in IVCU memory until the vehicle returns to the garage or until another off-peak period, at which time the data is read from IVCU memory and transmitted to the Radio Operator/Controller via radio communications. The radio communications could be via either the normal data channel or a separate spread spectrum system.

The second approach requires the use of a transferrable media device such as a "smart" card, an emerging technology, or a PCMCIA card, which are conunon on laptop PCS today. Data to be downloaded to the vehicle is stored on these small, pocket sized memory cards, which are then inserted into a card reader or slot on-board the vehicle by the Bus Operator. The data is read from the card and stored in the IVCUs memory. Likewise, data accumulated by the vehicle equipment can be written to the memory card throughout the service day and then read from the memory card when the Bus Operator returns the memory card to the Radio Operator/Dispatcher after the vehicle is returned to the garage.

The third approach transfers data via an infrared or similar probe. Data are transferred between the vehicle's IVCU and a separate computer that reads and/or writes data from/to IVCU memory via the probe interface.

The types of data that are typically transferred via these non real-time mechanisms are schedule and route data required by the vehicle, passenger count data, fare collection data, detailed operational data to be used for off-line planning and schedule analysis purposes, engine and transmission performance data, and paratransit manifest data.

Passenger Counting Devices

The technologies employed in automatic passenger counting (APC) sensors include infrared beams and pressure sensitive treadles located at each door of the vehicle. The sensors are arranged in pairs to detect whether a passenger is boarding or exiting the vehicle. The signals from the passenger detectors are interfaced to an on-board device that analyzes the signals and determines how many passengers boarded and exited the vehicle at each stop. These passenger counts can be combined with a vehicle location system so that the passenger counts can be correlated to the proper bus stops.

The passenger count and location data is then either transmitted over the radio or stored onboard for subsequent downloading, as described in Section "On-Board Data Storage & Retrieval." Once the data has been accumulated and processed, the data is typically used for service planning, monitoring passenger loading and schedule adherence, National Transit Database (NTD) reporting[1], analyzing bus shelter locations, establishing running times for new schedules, establishing ridership trends, and complaint analysis.

Various means have been employed for determining the vehicle's location at the time passenger boardings and exits are detected. Typically, the vehicle location methodologies utilized have been simplistic, low-cost approaches such as using odometers to measure the relative distance along the route and matching the recorded information with the scheduled profile of the route. Such approaches, however, have been subject to significant errors that have limited the accuracy and usefulness of the passenger count data. Many transit agencies who have implemented APCs have concluded that a more accurate and reliable location technology is required to support the APC function.

At Tri-Met, in Portland Oregon, the most significant problem they have experienced with APCs is in accurately correlating the received APC data with the proper bus stops. This problem, however, will be corrected once GPS-based AVL tracking is implemented in their new CAD/AVL system. In this new system, the APC data for each stop will be transmitted to the IVCU where it will be combined with the current GPS location and time. This data will be stored on board the vehicle and transferred to the central system for further processing after the vehicle returns to the garage.

[1] NTD (formerly Section 15) is an uniform system of accounts and records used to accumulate mass transportation financial and operating information. Reporting for the NTD is required by the Federal Transit Act

Problems have also been experienced with the passenger counting sensors themselves. Many sensors have been unreliable and have required considerable amounts of preventative and corrective maintenance to keep them functioning properly. The primary reasons for abandoning APCs amongst transit agencies have been the high development costs and problems with accuracy, software development, and maintenance.

Fare Collection Technologies

Considerable research and development has been conducted in fare collection equipment and media over the last few years. Transit agencies and vendors are researching many forms of electronic payment including stored value cards, credit cards, debit cards, contact smart cards, and proximity smart cards. Besides making transit more convenient for the passengers, transit agencies hope these new technologies will provide additional data on passengers and their use of the transit system, so that transit service can be improved to better meet passenger needs.

The data communications needed to support the fare collection equipment is dependent on the particular fare collection equipment and fare media employed. Data can be stored by the fare box and downloaded at the end of a service day, or data could be transferred in real-time to other on-board storage devices, or data could be transmitted to the radio communications system for further processing. If the fare data is to be correlated with vehicle location data so that it can be used for service planning purposes, a real-time data exchange between the fare collection equipment and the IVCU is needed.

Currently, most transit agencies that gather data from fare boxes do so by dedicated systems that probe the fare boxes when each vehicle returns to the garage. Fare boxes currently manufactured have limited, if any, capability for external interfaces. However, with the introduction of VANs and the increasing availability of passenger data from the fare boxes, it is expected that in the future, fare boxes will include external interfaces and will be interfaced directly to the VAN and integrated in with other on-board functions.

Audio Annunciation Devices

With the Americans with Disabilities Act (ADA)-mandated requirement to audibly announce all major intersections, transfer points, and stops specifically requested by a passenger, many different audible announcement products are available. These products vary in their degree of sophistication, automation, and cost. They cover the range of possible implementations from purely manual to fully automatic.

The manual approach is, of course, the most economical. However, problems with the audio quality, message consistency, and reliability are common drawbacks of this approach. Not all Bus Operators speak clearly enough for announcements to be understood by passengers and all drivers may not make all of the proper announcements at all of the required points.

These problems have led some agencies to implement semi-automatic designs. A typical semi-automatic approach is to have all the messages for a route pre-recorded in the proper sequence and to have the bus operator push a button when it is time for the next announcement. The advantages of this approach are reduced distractions and work load for the bus operator, consistency of the amouncements, and improved clarity since the recordings can be made by professional announcers under controlled conditions.

The next step up in complexity is to eliminate the bus operator's involvement altogether by automatically triggering the announcements based on the vehicle's actual progression along the route. For this approach, the velicle's location is determined by AVL equipment. Automatic announcements are then triggered based on progression of the vehicle's location along its assigned route. The information being audibly annunciated to the passengers on-board the bus can also be displayed on passenger information displays located inside the bus. Automated announcement systems also make it possible to intersperse promotional, public service, and advertising messages. These announcements can be made at preset times, before particular stops, or a combination of both location and time.

In addition to audio announcements for passengers on-board the bus, separate announcements can also be made to passengers boarding the bus. These announcements are made via external or stepwell mounted speakers and typically inform the passengers of the bus route and destination. The digital technologies that can be used in audio announcement systems include synthesized, digitally-recorded, and digitally-constructed technologies. In the synthesized approach, the audio announcement is generated by the audio announcement equipment based upon an American Standard Code for Information Interchange (ASCII) string of data passed to it. The voice clarity of this approach is poor and for this reason, synthesized announcements have not been approved for meeting ADA announcement requirements.

Digital-recording provides a high quality recording of the messages but can be very memory intensive, depending upon the digital compression techniques that are used. In addition, digital-compression approaches further reduce memory requirements by building messages from discrete words and phrases. This allows common words like street names to be recorded once instead of each time they are needed. The digital approaches also provide multi-lingual capability and full-range audio. The full-range audio capability allows sound effects and music to be included in the promotional, public service, and advertising messages.

COMPUTER-AIDED DISPATCH TECHNOLOGIES

Modern Computer Aided Dispatch (CAD) systems employ a host of improvements over the systems produced 10 years ago. Most modern systems are much more user friendly and adaptable to the users specific requirements. Graphical user interfaces, high-resolution color displays, automatic and ad-hoc report generators, expandable distributed systems architectures, increased data communications, and interfaces to other computer systems are standard features of most modem CAD systems.

The graphical user interfaces are typically 'windows-based', e.g., with a graphical user interface, and are designed to allow users to perform conunon tasks quickly and efficiently. Report generator software makes it easier to generate and modify system reports with a minimum of programmer involvement. Ad-hoc reporting capability is also provided with many systems to allow the data acquired and stored by the system to be analyzed as needed in special situations. System reports are designed to automatically retrieve data stored in the database or known to the system so that user data entry is minimized.

The most common computer architecture is a distributed processing environment that places more intelligence and processing at the console workstation level so as to minimize the central processing requirements. This architecture helps minimize the impact of peak loading conditions and allows user consoles to be more readily added in the future.

Data communications with the vehicles are designed to provide rapid reporting and response to important situations and efficient transmission of routine communications. Communications protocols used by vendors include polling, non-polling, and combinations of polling and non-polling techniques. Many support exception reporting schemes to minimize communications traffic and some support smart polling/reporting techniques to allow more frequent reporting from vehicles that have active emergency alarms or are off schedule.

When AVL is implemented, features are typically provided to integrate the CAD and AVL functions. For example, when an emergency alarm is indicated, selection of the vehicle from the CAD call queue can cause the AVL map display to be centered on the vehicle in alarm. In some systems, as the vehicle moves, the AVL map is automatically moved to keep the vehicle in alarm centered on the display.

The map displays used for the AVL function are based on commercially available geographic information system (GIS) maps that can be supplemented with the transit specific route and bus stop data. The standard map display and manipulation features, such as cluttering, decluttering, panning, and zooming are supported. Routes are highlighted on the maps and the current vehicle locations are identified by vehicle symbols that include the vehicle ID and/or route/run number and color coding to indicate the vehicle status. Detailed information about a particular vehicle can be determined by selecting the vehicle on the display.

The system interfaces supported by each CAD system vary between transit agencies, but typically interfaces are provided to a Management Information System (MIS) and to scheduling. Other possible interfaces include interfaces to trip planning systems, geographic information systems, passenger information systems and traffic management systems.

SYSTEM COMMUNICATIONS

As part of the overall AVL System, it will be critical for the Solano Transit Operators to implement a mobile wireless network since the system is based on a transit fleet of mobile vehicles traveling throughout the County all needing to communicate with a fixed dispatch facility. Listed below are some issues to consider with this network.

There are National Public Safety Planning Advisory Committee (NPSPAC) radio channels available for use. We have listed some issues to address when obtaining a license to use these channels.

a) If the transit operators in Solano County were to own and operate its own radio system, it would need to license at least five channels, with a eight channels being desirable.

b) If the transit operators in Solano County were to participate in a shared radio system with other public agencies, it would likely need separate and dedicated channels for transit data (e.g., data messages, AVL data, etc.) in order to eliminate network latencies attributed to network congestion, i.e., transfer of information between agencies would be on different channels from the transfer of information between transit vehicles and dispatch.

c) The transit operators in Solano County may be required to contribute additional channels to a shared radio system in order to participate.

d) If the transit operators in Solano County were to obtain and use the existing Nextel trunked radio system equipment for the short term (i.e., until a new radio system were in full operation), it would need temporary licensing for at least five channels at least until a private network is built.

RADIO TECHNOLOGY ALTERNATIVES

Conventional Radio System

The conventional (non-trunking) method of two-way mobile radio operations, which has existed since the beginnings of mobile radio, is a system where all radio users who have a need to intercommunicate are assigned a fixed radio frequency, or channel. When a user wishes to talk, he/she monitors the channel to determine if it is available, and transmits when the channel becomes idle. All other users assigned to that channel, and within radio range, will then hear the transmitted signal. The channel is essentially a "party line," with all users contending for its capacity and all messages open to all listeners. If the channel is busy, the user must wait for an idle period.

This method is inefficient, in that, if the aggregate traffic requires more than one channel, there is no traffic sharing among channels, and one channel can be idle while another is overloaded.

Data messages are readily transmitted over conventional radio systems, with bandwidths limited to about 4800 bits per second (bps). Any bandwidth higher than this causes the bit error rate becomes excessive, despite error correction techniques. The digital data messages are converted to analog signals for wireless transport at the transmission points, and then reconverted back to digital signals at the receiving points.

Conventional systems involve the simplest of radio system architectures, consisting mainly of base station transceivers, field units, voters (if required), and simple signaling devices. These systems, therefore, are the least expensive type of radio system to implement and maintain.

It is unlikely that a modern transit radio system would be based on the conventional radio technology.

Trunked Radio System

The trunked method of two-way mobile radio operations provides each user with automatic access to several radio channels, or "trunks," rather than just one. The aggregate traffic of many users is thereby efficiently distributed over several radio channels. Users that have a common need to intercommunicate are assigned to "talkgroups," rather than to a specific radio-frequency channel.

A primary advantage of trunking systems is that they make much greater effective use of radio channels, which are in short supply in most populated areas. Modem trunked systems designed for public-safety applications provide a wide range of operating features specific to those agencies' needs. However, many of these features are not useful for transit applications.

Trunked Transit Radio Systems

Modem transit radio systems function according to the basic principle of trunking, in that they distribute radio traffic among several radio channels, and therefore efficiently load those channels and reduce the probability of blocking. Also, they typically use one or more separate data channels to control voice channel assigment, traffic distribution, and other operating features, similar to other trunking systems. Transit radio systems using trunking principles are sometimes colloquially described as "quasi-trunked."

Typically, trunked transit radio systems are not designed to provide the features of public safety systems, and it does not comply with the Association of Public Safety Communications Officials (APSCO) standards.

Analog Radio System

In an analog voice signal transmission, the voice signal input is modeled as an electrical signal (varies as the intensity of sound); the electrical signal is essentially an analog representation of the sound waveform. That electrical signal is used to modulate the radio-frequency carrier that is transmitted over the air. The receiving radio demodulates the carrier to recover the varying electrical signal, and uses it to drive a loudspeaker, which converts the electrical signal back into soundwaves, to be heard by the called party.

Until the last several years, essentially all land mobile radio systems operated on an analog basis. While analog technology has been utilized quite extensively in the past, the support by radio suppliers appears to be diminishing. Most suppliers are moving towards an all-digital network where voice and data can be transported more efficiently and effectively. It is not recommended that an analog radio system be considered for the Solano County Transit AVL System.

Digital Radio System

Digital technology has been used in the telephone industry for over 25 years, and has been adapted to compact discs, cordless telephones, and most other communications storage and transmission media. Digital cellular telephone systems are currently beginning to be implemented. Digital television is under development. Computers are, of course, entirely digital.

Digital transmission equipment has become available for land mobile radio systems over the past few years. Some characteristics that distinguish it from analog transmission are as follows:

a) The digitized voice quality is somewhat lower than that of an ideal analog system, because the voice signal is encoded into a relatively low data rate so that it can be transmitted within the narrow bandwidth of the radio channel. Higher bandwidth channels enable superior voice quality for digital compared with analog.

   Digital transmission also provides more uniform voice quality than analog transmission over the entire range of radio coverage. Typically, the voice quality of an analog system diminishes as a function of the distance from the transmitter, because of progressive lessening of the signal strength. In contrast, the voice quality in a digital system is quite uniform; it is slightly poorer than analog in the immediate vicinity of the transmitter, but then retains the same uniform quality out to the ultimate range of the transmitter, at which point it degrades into uselessness very rapidly.

(b) Because the voice signal is encoded into a digital bit stream, a digital transmission system can carry voice or data equally well.

(c) Digital transmission is inherently more private than analog because the digital signal must be decoded to be understandable, which is not possible with currently-available analog scanners. However, there is little doubt that digital scanners will become available to the public.

(d) It is relatively simple and inexpensive to add encryption to digital transmission, because the signal is already digitally encoded. However, this has been of little interest to most transit agencies.

   While digital transmission is a relatively recent development in land mobile radio, it is otherwise a mature technology, and therefore considered to have relatively low technical risk. Given the communications industry's move into the digital networks, technical and technological support is anticipated to be robust.

Digital systems that have been quoted recently by major manufacturers are more costly than equivalent analog systems. We estimate an added cost of approximately 20% for the radio transmission equipment, which includes repeaters, mobile and portable radios, and control stations.

Cellular Communications

Portable/mobile telephone capability is available to individual businesses and private users by subscribing to the service offered by cellular phone companies. The operating features of cellular phones are essentially the same as those provided by regular local and long distance telephone companies, and the same Public Switched Telephone Network (PSTN) is used to provide the nonwireless person-to-person connection between any two telephones.

The use of a cellular system for communications between a central dispatch facility and a fleet of vehicles could be viable if the communications requirements were very similar to the types of communications that the cellular systems were designed to address; that is, infrequent voice communications between the central dispatch facility and one vehicle at a time. However, with AVLS where the continuous exchange of real-time information is required, cellular systems are not a viable option. With an ALVS, there is the need to support dynamically configurable group calls to the fleet, rapid and reliable responsiveness in emergency situations, and the intermixing of extensive and frequent data transmissions. Celular service may have application for a small number of vehicles that service remote routes that are not within the normal radio coverage area.

In addition to the operational problems that would be present when using a cellular system for fleet dispatching and data transmissions, specialized central and mobile unit equipment and software would have to be developed in order utilize a cellular system for dispatch operations. Such development would be costly and there appear to be no immediate plans by the cellular providers to address these requirements.

Cost would also be a significant factor, particularly considering the need for frequent data transmissions. Some cellular providers charge a minimum of one minute usage for each call. Therefore, typical data transmissions that could be completed in a fraction of a second would be billed as a minute of air time.

Video

At present, the large amount of data inherent in video images and the bandwidth constraints of radio channels combine to make video transmission, even of still-frame video images, currently impractical. While conceptually feasible, video transmission would occupy the bus radio channel for a significant length of time (many seconds) and prevent any other data or voice communications during that interval. Additionally, the usable quality of the video image would also be questionable.

Suppliers of video equipment for transit vehicles are currently developing methods and equipment with improved compression capability, and such systems may enable the transmission of images in the future. Presently, however, these systems have not been installed and tested in actual transit vehicle operations, so image quality and transmission time results are not yet known. Continued attention should be given to these developments and possible improvements in compression and transmission techniques could allow video transmission to be practical and affordable in the near future.

ANN ARBOR TRANPORTATION AUTHORITY ADVANCED OPERATING SYSTEM

The Ann Arbor Transportation Authority (AATA) of Michigan introduced a new Advanced Operating System (AOS) on its buses that goes far beyond just meeting ADA requirements. (see Figure 2). It is the first fully integrated, public transit communication, operation, and maintenance system in the United States. The AOS includes advanced electronic technologies like DGPS, Automatic Vehicle Location (AVL), "Smart" Cards, Computer-Aided Dispatching, and automated vehicle-component monitoring.

Drivers use the Mobile Display Terminal's (MDT) "low work-load" screen and "smart keys" to send and receive messages to and from the dispatch center. Also, they use the MDT to operate all the advanced onboard systems including a two-way radio system. AATA buses are equipped with an 800 MHz radio and onboard computers. Voice transmissions are minimized by using data messages that report vehicle status, operating condition, and location. During routine operation, the vehicle sends the information over a data channel. For voice communications between driver and dispatcher, the radio is switched to a voice channel.

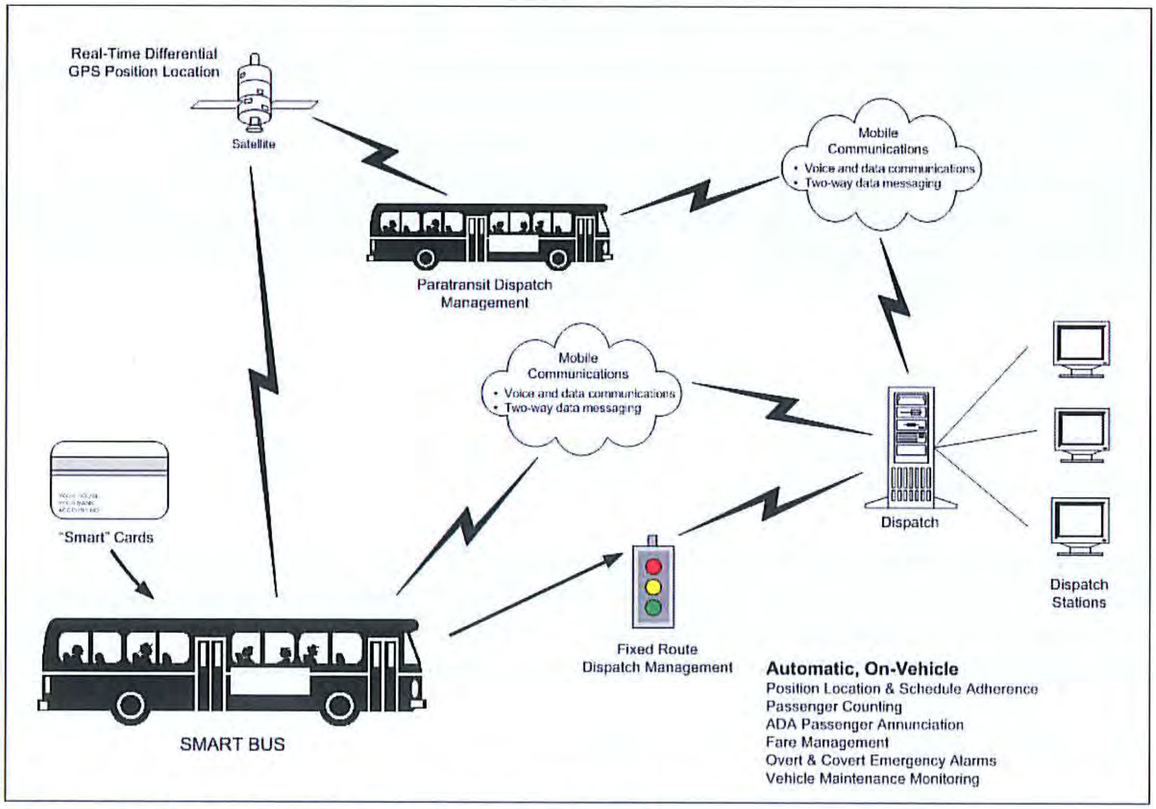


Figure 2 – AATA Advanced Operating System Overview

Differential Geographic Positioning System (DGPS) is a key ingredient of the AOS. This enables the Automatic Vehicle Location System to pinpoint bus locations to within three to six feet. Onboard computers store complete route schedules, and GPS provides accurate time to the vehicles. Scheduled times and locations are compared with actual locations to determine if the buses are on time. If a bus is off schedule, the driver is advised, and if necessary, the onboard computer notifies the Operation Center.

The AVL system triggers visual displays and audible announcements both inside and outside the bus. Announcements and displays include next stop information, stop requests, current time, and other messages to keep riders informed. The AVLS also generates en route information, provides location information for fare collection, and gives the driver pacing information.

The AOS not only benefits drivers and dispatchers, but the management of the AATA. Automated Passenger Counters in the system automatically counts passengers as they board and leave AATA buses. AATA management can then use that information for planning routes, assessing ridership patterns, and developing new services. For fleet managers, the Vehicle Component Monitoring system includes engine sensors that continuously monitor certain elements within the bus including oil pressure, temperature, and others. Any "out of bounds" values are reported in real-time to the onboard computer, the Operations Center, and the Maintenance Department. The AOS now includes data collection of farebox cash payments, and in the future could include cashless fare payment via "smart cards."

Riders transferring from one bus to another during their trips will benefit Computer-Assisted Transfer Management since this provides more reliable service. Using the system software, drivers receive transfer requests that they will encounter in the next several minutes. The computer at the dispatch center determines whether requested transfers are possible and informs the driver on the display if a transfer is accepted. Once the transfert is accepted, the dispatch computer sends a message advising the driver to wait for the transferring passenger. Eventually riders will be able to access schedules, as well as other information in real-time through AATA kiosks, and through public access cable television during peak service times.

Computer-Aided Dispatching software also benefits riders by allowing reservations, more flexible scheduling, and integration of special services such as paratransit services with fixed routes. Using integrated scheduling and AVLS software, AOS allows flexible routing of public transit services such as on-demand paratransit services with intelligent scheduling.

If a driver encounters a life threatening emergency, the driver can alert the dispatcher, who can instantly find the location of the bus on a map, and notify the appropriate agency for assistance. The system can also be used for reporting routine, non-life-threatening situations. For further passenger and driver safety, AATA's newer buses are equipped with a video-monitoring system. This video system records on videotape for later playback with one camera able to record audio. Other buses are equipped with a two-camera digital system.

STANDARDS AND INTEROPERABILITY

ITS standards are specifications that define how system components interconnect and interact within the overall framework of the National ITS Architecture. The National ITS Architecture is an ITS framework developed by the Federal Highway Administation (FHWA) and the Federal Transit Administration (FTA) that outlines how ITS elements are to be implemented so as to be consistent with all other ITS elements from differing jurisdictions and systems.

The ITS Standards Program is working toward fostering the widespread use of interoperatable ITS components by accelerating the development and implementation of ITS Standards. This is essential for achieving the interoperability and compatibility necessary to function consistently and effectively nationwide. In short standards specify how to do things consistently, to:

- Enable compatibility and interoperability
  - Adjoining products/systems can work together cooperatively
  - Ability to interconnect devices from different manufacturers
  - Same product will operate correctly and consistently
- Manage overall cost
- Ensure product and service quality
- Enhance service reliability
- Expedite acceptance and implementation of products and services.

By specifying how systems and components interconnect, the standards promote interoperability. The interoperability is the ability of ITS elements:

- To provide information and services to other systems
- To accept information and services from other systems
- To use the information and services that are exchanged between agencies and subsystems to operate together effectively.

This will ensure that mobile users who travel across the Bay Area and the rest of the nation will get the same level of any of the ITS services offered. There are three types (levels) of ITS interoperability that Solano County Transit ITS Program should be concerned with:

- Technical – that is the ability of equipment (hardware and software) to communicate effectively (i.e., send and receive information)
- Procedural – common procedures to exchange meaningful information
- Institutional – administrative and or/contractual agreements between operators and users of the information.

These interoperability types are being developed under the ITS Standards Program. As more and more field implementations are completed, the lessons learned from these will be utilized in the Solano County ITS Program.

How Can Standards Benefit Solano County Transit ITS Program?

The transit operators in Solano County are committed to conform with all applicable ITS standards that have been developed, or is currently under development (see www.its-standards.net). The level of confomity will depend on the status of development of the specific standards and the level of implementation of the standards by the product manufacturers. The use of ITS standards provides the following benefits:

- Forward and backward compatibility of devices, and interoperability of ITS elements
- Lower risk of being locked into proprietary products
- Ability to procure products from different manufacturers
- Reduces risk of product becoming obsolete
- Reasonable assurance of quality.

The Solano County Transit ITS Plan Concept of Operations details a listing of the potential ITS standards required for a Countywide AVLS.

SOLANO COUNTY TRANSIT ITS STRATEGIC PLAN

Appendix B
Consortium Presentations and Workshop Minutes

- Automated Vehicle Location System/ Transit Priority Control System (AVLS/TPCS) Presentation to SolanoLinks Transit Consortium (January 3, 2002)
- AVLS/TPCS Workshop Minutes (held in Fairfield, CA on April 23, 2002)
- AVLS/TPCS Workshop Minutes (held in Vallejo, CA on May 9, 2002)
- AVLS/TPCS Functional requirements Presentation to SolanoLinks Transit Consortium (May 29, 2002) and feedback received at meeting.

SOLANO TRANSIT OPERATORS INTELLIGENT TRANSPORTATION SYSTEM

Automated Vehicle Location (AVL) & Transit Priority Control System (TPCS)

Presentation by
DKS Associates
January 3, 2001

What is an Automated Vehicle Location (AVL) System?

- A central control system that can automatically perform the following:
  - Tracking of the location of transit vehicles
  - Providing prediction of travel and arrival times for transit vehicles
  - Enabling intelligent priority/preemption for transit vehicles
  - Providing a silent alarm activated by a driver in an emergency
  - Providing vehicle component monitoring (e.g., high engine temperature is flagged and dispatch notified)

2

Potential Features of an AVL System

- Route history for scheduling
- Transit preemption
- Real-time information
- Message signs at transfer points
  - Vallejo Ferry Terminal
  - Downtown Vacaville
  - Fairfield Transportation Center
- Voice announcements at stops
- Vehicle location for dispatch
- Traveler information over the Internet

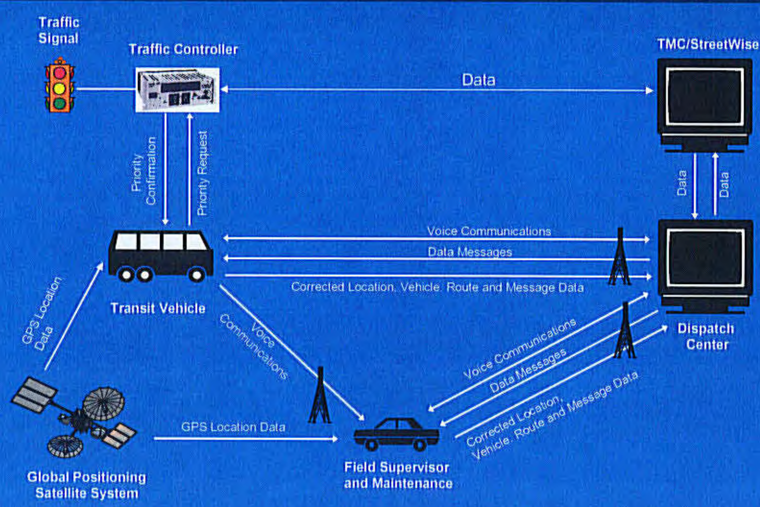
3

Existing AVL Systems

- Denver Regional Transit District
- San Francisco Municipal Railway
- Oakland AC Transit
- San Jose Outreach
- Ann Arbor, Michigan
- Montgomery County, Maryland
- Dallas Area Rapid Transit
- Houston

4

Key elements of a typical AVL and TPC System



5

Benefits of an AVL System

- Benefits to users at each boarding
  - when, where, and how
- Key benefits to operators
  - productivity = riders per service hour
- Double benefit of AVL and TPCS – new riders attracted and platform hours reduced
  - Minimized wait time, travel time
  - Improve on-time reliability
  - Better information during trip

6

Issues that can be addressed with an AVL System

- Incidents
  - Traffic delay
  - Passenger safety
- Fixed-route planning
  - Capacity
  - Productivity
- Paratransit services
  - Routing
  - Paratransit equipment allocation
- Route planning
  - Schedule adherence
  - Street engineering issues
- ADA issues
  - Wheelchair origins/destinations
  - Stop announcements
- Schedule adherence monitoring
- Automated fare payment systems

7

Key design issues with AVL systems

- Keep the technology simple
- Select a cost effective integrated system
- Select a scalable and integrated system
- Select a system that adapts to new and changing technology at minimum cost
- Time and latency a critical design factor
- Solution based on national standards

8

Issues for an AVL System in Solano County

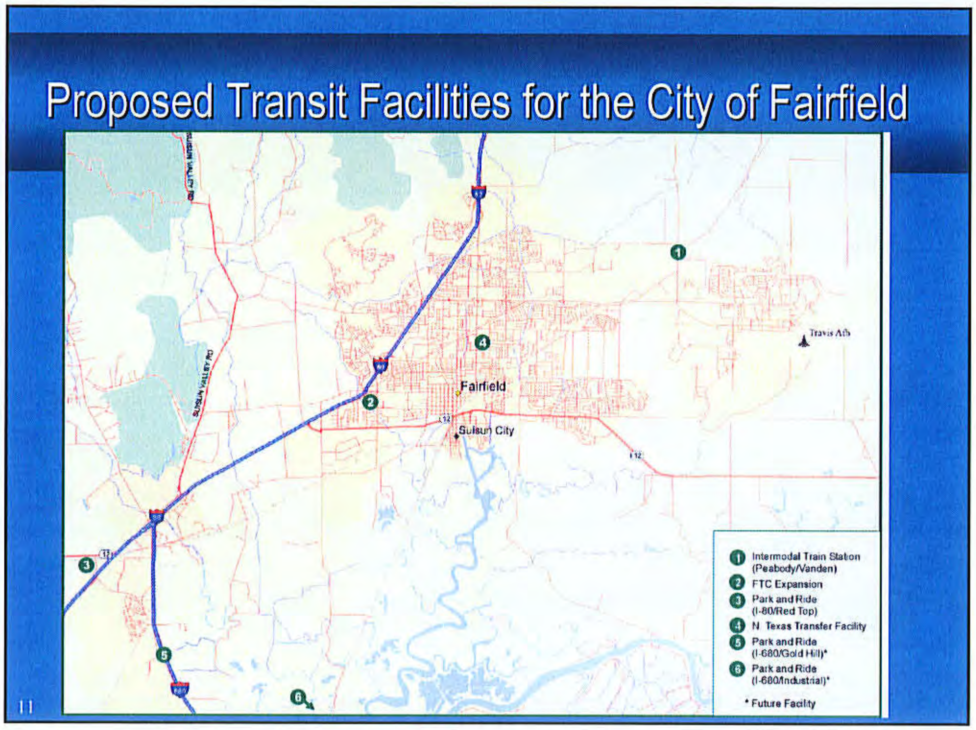
- The design of the AVL System will require input from all agencies and transit operators (buy in)
- The system will be expandable to include at least the entire County, and all transit systems
- The needs of the transit system will need to be balanced with maintenance and operational requirements
- A wireless communications voice/data network will need to be implemented

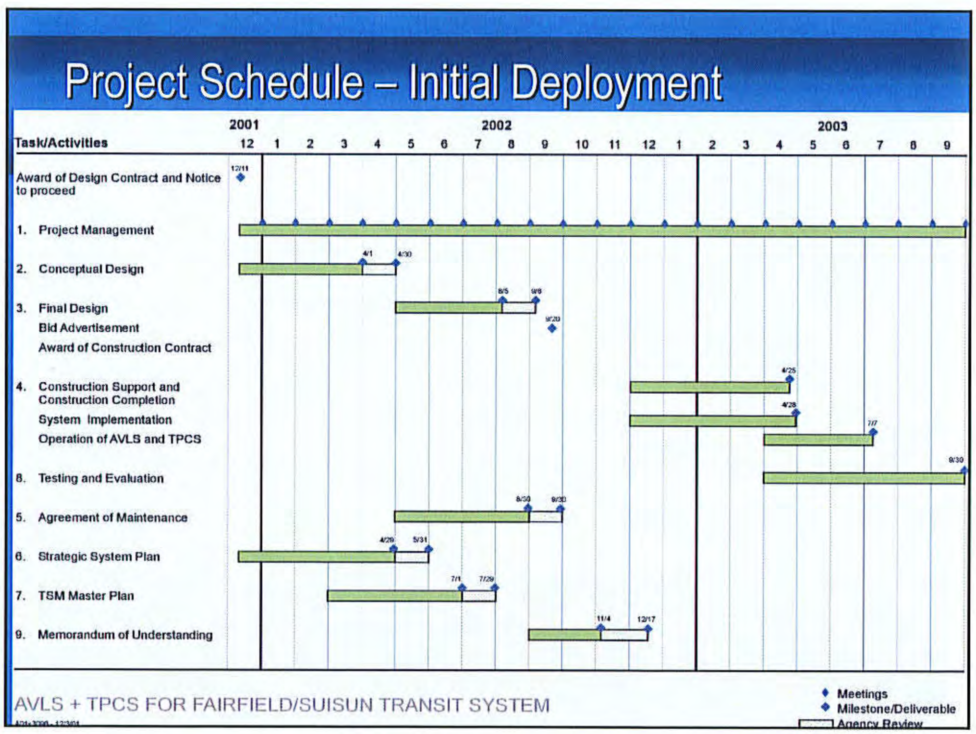
9

Issues for an AVL System in Solano County

- The AVL system will need to bridge the gap between the TPCS and each agencies' traffic and transit system
- The AVL system will need to collect passenger and schedule information
- Automated paratransit scheduling will need to be evaluated in detail
- The system will be based on National ITS standards

10


Proposed Transit Facilities for the City of Fairfield
Fairfield
Suisun City
Travis Afb
SUISUN VALLEY RD
1 Intermodal Train Station (Peabody/Vanden)
2 FTC Expansion
3 Park and Ride (I-80/Red Top)
4 N. Texas Transfer Facility
5 Park and Ride (I-680/Gold Hill)*
6 Park and Ride (I-680/Industrial)*
* Future Facility
11


Project Schedule – Initial Deployment
Task/Activities
2001
2002
2003
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
Award of Design Contract and Notice to proceed
12/11
1. Project Management
2. Conceptual Design
4/1
4/30
3. Final Design
Bid Advertisement
Award of Construction Contract
8/5
9/6
9/20
4. Construction Support and Construction Completion
System Implementation
Operation of AVLS and TPCS
4/25
4/28
7/7
8. Testing and Evaluation
9/30
5. Agreement of Maintenance
8/30
9/30
6. Strategic System Plan
4/29
5/31
7. TSM Master Plan
7/1
7/29
9. Memorandum of Understanding
11/4
12/17
AVLS + TPCS FOR FAIRFIELD/SUISUN TRANSIT SYSTEM
Meetings
Milestone/Deliverable
Agency Review

Fairfield AVL Workshop Minutes
(held at Fairfield Transportation Center)
April 23, 2002

Attendees:

- Kevin Daughton (Fairfield)
- Ray Chong (Fairfield)
- Pam Gillam (Vallejo)
- Gian Aggarwal (Vacaville)
- Trent Fry (Vacaville)
- Dan Christians (STA)
- Janice Carey (ZEG)
- Habib Shamskou (DKS)
- Elbert Chang (DKS)

Habib presented status and direction of project and seek feedback (PowerPoint)

Comments/Feedback:

- Presentation needs to include benefits/ cost-savings of AVL system. Vallejo needs "real world" examples of benefits to justify costs.
- Fairfield's Initial Focus of deployment is operational improvements and data collection- dispatch and other back-end improvements have higher priority than kiosks. System (equipment & operators) really needs to work well before unveiling to public)
- Vacaville's primary interest is in talking bus, voice enunciation.
- Pam requested presentation in Vallejo for dispatch operators, other City staff and management.
- Participants agreed on County-wide deployment. Location of buses shared between agencies. Cities' want the ability to see other agency buses in the city.

Action:

- DKS to incorporate comments into presentation and present to Vallejo.
- Future presentation may be at SolanoLinks Transit Consortium Meeting in future. Kevin Daughton to place on SolanoLinks agenda.

SOLANO COUNTY TRANSIT ITS PLAN
AUTOMATED VEHICLE LOCATION SYSTEM (AVLS) AND TRANSIT PRIORITY CONTROL SYSTEM (TPCS)

Vallejo Workshop
City of Vallejo Department of Public Works
Main Conference Room
555 Santa Clara Street, Vallejo CA 94590
Thursday, May 9, 2002, 9am – 11am

ATTENDEES:

John Harris, Vallejo	707.648.5241	jharris@ci.vallejo.ca.us
Taner Aksu, Vallejo	707.648.4300	taksu@ci.vallejo.ca.us
Pam Gillam, Vallejo	707.553.7224	pgillam@ci.vallejo.ca.us
Guia Del Rosario, Vallejo Transit	707.648.4671	gdelrosario@vallejotransit.com
Michael D. Setty, Vallejo	707.557.7563	carquinz@scrserv.com
Kevin S. Daughton, Fairfield	707.428.7641	kdaughton@ci.fairfield.ca.us
Rich Sauve, DKS	510.763.2061	rts@dksassociates.com
Habib Shamskhou, DKS	510.763.2061	its@dksassociates.com
Elbert Chang, DKS	510.763.2061	ekc@dksassociates.com

MEETING MINUTES:

DKS Associates presented the Solano County Transit ITS Plan (a 20-year vision) and the initial AVLS/TPCS implementation (3-5 years) with its associated costs. The total AVLS/TPCS system equipment is projected to cost $10 million, with $2.2 million already secured by Fairfield for the initial stage of the AVLS/TPCS. Vacaville has secured an additional $800,000 that could be used to complement the initial AVLS/TPCS deployment.

Vallejo is concerned with how much time and dollars they might need to commit to this project. Also, they are concerned that the $10 million cost estimate will increase over time and that technology changes/improvements may require costly upgrades in the future.

Vallejo sees positive aspects of implementing a AVLS/TPCS for Vallejo Transit, but expressed strong concerns regarding capital and maintenance costs. Funding for Vallejo Transit will be tight and they cannot make additional financial commitments at this time. There are several other un-funded capital project priorities that would be ahead of the AVLS/TPCS.

Vallejo views on-going maintenance costs to include both hard and soft aspects. Hard costs include software licensing and upgrades, physical part replacements and other maintenance costs. Soft costs include additional staff time, new training, and other similar costs. Vallejo would like to see a detailed breakdown of the AVLS system and how its implementation would be phased. The RFI under development to AVLS/TPCS operators should include information on operation and maintenance costs.

There was some discussion regarding moves in funding for O&M (Future county sales tax, TEA-21), but none of this is currently secured.

Fairfield sees the AVLS/TPCS implemented in phases for the county. These phases include functional and location. Fairfield sees their initial priority on real-time location equipment on the buses and dispatch upgrades. Functions such as automated passenger counts and real-time passenger information devices (kiosks, bus-stop signs) would be added later after the system proves its reliability and value. Fairfield, Vallejo and Vacaville would implement the AVLS/TPCS system first.

Vallejo questioned the usefulness of the initial system if it only focused on providing location information for operators. Fairfield pointed out the system could be used to create more accurate and time of day specific schedules. Currently, collecting such data is staff and capital intensive. Having the basic AVLS system in place would allow data to be collected more often and in a less costly manner.

Vallejo Transit only has one dispatcher on duty and expressed concern that the system not add complexity and complicate dispatch operations and duties. The system should help the dispatcher.

Vallejo does not have a TMC and doesn't see it as necessary for the implementation of the TPCS. Automatic implementation of TPCS is acceptable so long as it follows pre-agreed upon parameters that take into account characteristics such as how late the transit vehicle is and the current traffic signal operation.

Vallejo recommended that STA be involved to help keep the AVLS/TPCS project moving. Implementation strategy sessions need to be held with STA; all key players should be at the next meeting to discuss this project, including Vallejo, Vacaville, Fairfield, STA.

ACTION ITEMS:

- DKS to continue to seek input into the Solano County Transit ITS Strategic Plan from stakeholders over the next two months.
- DKS to prepare cost estimate for AVLS/TPCS system and phased implementation. Cost estimate to include operating costs (including hard costs and staff time.)
- DKS to incorporate request for O&M costs in RFI.
- DKS to arrange for strategy session with STA.

SOLANO COUNTY TRANSIT ITS PLAN
AUTOMATED VEHICLE LOCATION SYSTEM (AVLS) AND TRANSIT PRIORITY CONTROL SYSTEM (TPCS)

Feedback to May 29, 2002 presentation of AVLS/TPCS High-Level Functional Requirements at SolanoLinks Transit Consortium Meeting. (Feedback received at meeting.)

- System should be capable of all functions listed, but each jurisdiction should have the choice of which function to "turn-on" at a appropriate time.
- Implementation of the system and functions would likely be phased. The initial stage should include dispatch upgrades and functions would be added as each phase proved itself.
- Concern was expressed regarding cost of operating system upgrades necessary to support this system (soft cost). Vallejo is in process of moving to Windows 2000, but high-level requirements specify software to be Windows NT. AVLS vendors write software for the most common operating systems used by customers. It was pointed out that City's would likely need to upgrade operating systems regardless of whether the AVLS were implemented. Requested that RFI include Operations and Maintenance Costs (both hard costs and soft costs) of deployed systems.
- The system should use City communications infrastructure for center-to-transit vehicle communications to avoid recurring costs. A County-wide communications system may allow support costs to be shared.
- The system information signs could be included at Park and Ride Lots.
- The system should provide an interface with TransLink (MTC/Bay Area one-card system for public transit). Vallejo is looking at using TransLink for OD data collection and questioned if AVLS system could also provide this info. Automated Passenger Counts is one of the AVLS high-level requirements, but provides on-off data, not specific trip data.
- The system should integrate with TravInfo (MTC/Bay Area traveler information system)
- Some members expressed interest in a field visit to see Stockton's system. Other nearby deployments include Valley Transportation Authority and AC Transit.
- Polling rate for GPS location information from vehicle should be user-definable.

SOLANO COUNTY TRANSIT
ITS STRATEGIC PLAN

Appendix C
Transit ITS Architectural Flow Diagrams

Appendix C provides a brief overview of the composition of the architectural flows within the National Intelligent Transportation System (ITS) Architecture. These are followed by a description of market packages that are applicable to the Solano County Transit ITS Strategic Plan. The descriptions are from the National ITS Architecture.

Overview

There are three concepts that require further definition for a complete understanding of architectural flows and market packages.

1) **Subsystem** – Each subsystem is a cohesive set of functional definitions with required interfaces to other subsystems. Subsystems are functionally, not physically, defined. There are 19 subsystems in the National ITS Architecture. They are grouped into four classes: Centers, Roadside, Vehicles, and Travelers.

Example: A regional implementation may include a single physical "brick and mortar" center that collocates the capabilities from several Subsystems. For instance, a single Transportation Management Center (TMC) may include Traffic Management Subsystem, Transit Management Subsystem, Emergency Management Subsystem, and Information Service Provider Subsystem functionalities. On the other hand, a single Subsystem may be replicated in many different physical "brick and mortar" TMCs in a complex metropolitan area system. For instance, multiple traffic management subsystems may be implemented in a region reflecting distinct State freeway and local arterial management centers.

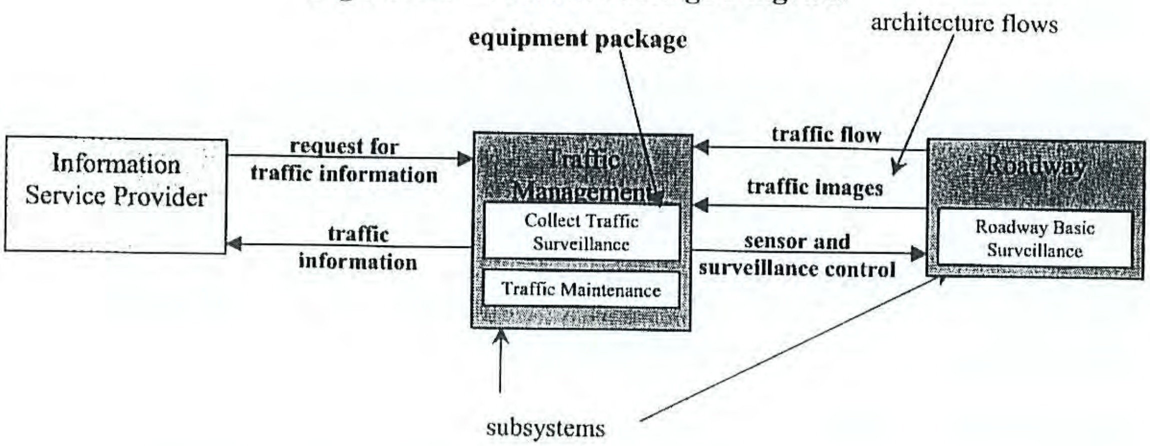
2) **Equipment Package** – A market package is implemented with a combination of interrelated equipment. An Equipment Package represents a set of equipment/capabilities that are likely to be purchased by an end-user as a component to an overall system. This equipment often resides in several different Subsystems within the Architecture Framework and may be operated by different stakeholders. Since Equipment Packages are both the most detailed elements of the Physical Architecture and associated with specific market packages, there is clear traceability between the interface-oriented Architecture Framework and the deployment-oriented market packages.

Example: The Transit Vehicle Tracking Market Package includes vehicle location equipment in the Transit Vehicle Subsystem and a base station element in the Transit Management Subsystem. In this example, all market package elements are owned and operated by the same transit stakeholder. In other cases, the market package elements are owned and operated by different stakeholders. Many of the ATIS market packages require equipment in the Information Service Provider Subsystem that is owned and operated by a public or private information provider and equipment that is acquired and operated by the consumer as part of the Vehicle Subsystem or Personal Information Access Subsystem. Since equipment in different Subsystems may be purchased and operated by different end-users, these Subsystem-specific components may encounter varied deployment.

3) **Architecture Flows** – Architecture Flows are the information and data exchange between and among various Equipment Packages and Subsystems. The Architecture Flows allow for a coordinated overall system operation by following pre-defined interfaces between equipment and subsystems which may be deployed by different procuring and operating sectors.

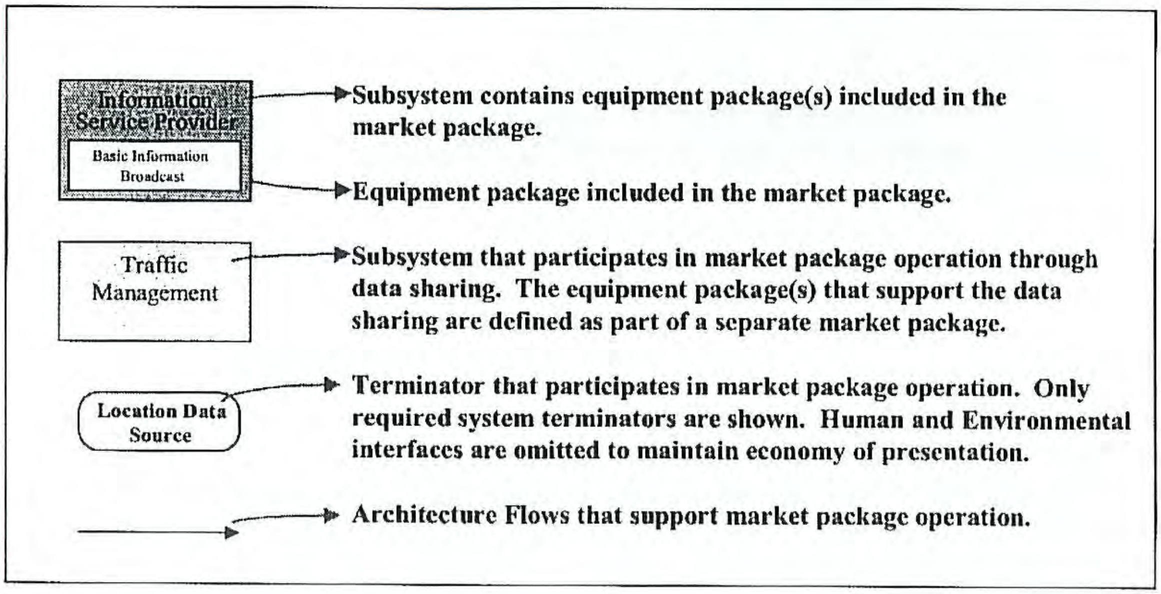
To give a more visual understanding of a market package, Figure C.1 shows a market package diagram, and Figure C.2 is a legend to assist in understanding the diagram. In general, only the most salient elements from the architecture definition (e.g., directly involved subsystems, system terminators, and the highest level data flows) are depicted in each graphic to ensure clarity.

Figure C.1 – Market Package Diagram



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

Figure -C.2 – Market Package Diagram Legend



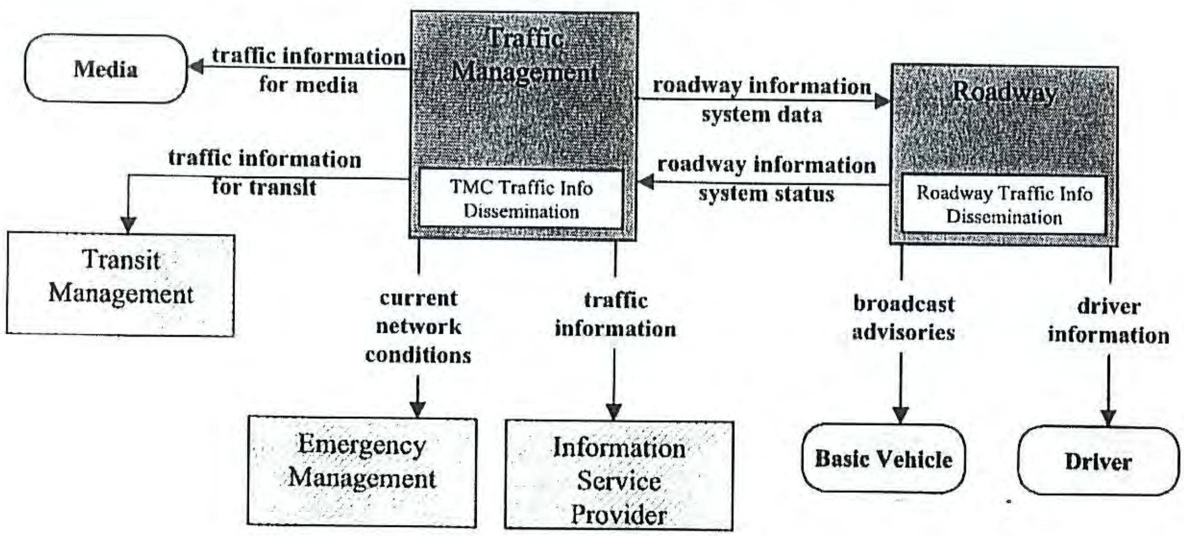
*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

The following descriptions of market packages that are applicable to the Solano County Transit ITS Strategic Plan are taken from the National ITS Architecture. These market packages are grouped as follows:

- Traffic Management Market Packages;
- Public Transportation Market Packages;
- Traveler Information Market Packages;
- Advanced Vehicle Safety System Market Packages;
- Commercial Vehicle Operations Market Packages;
- Emergency Management Market Packages;
- Archived Data Management Market Packages.

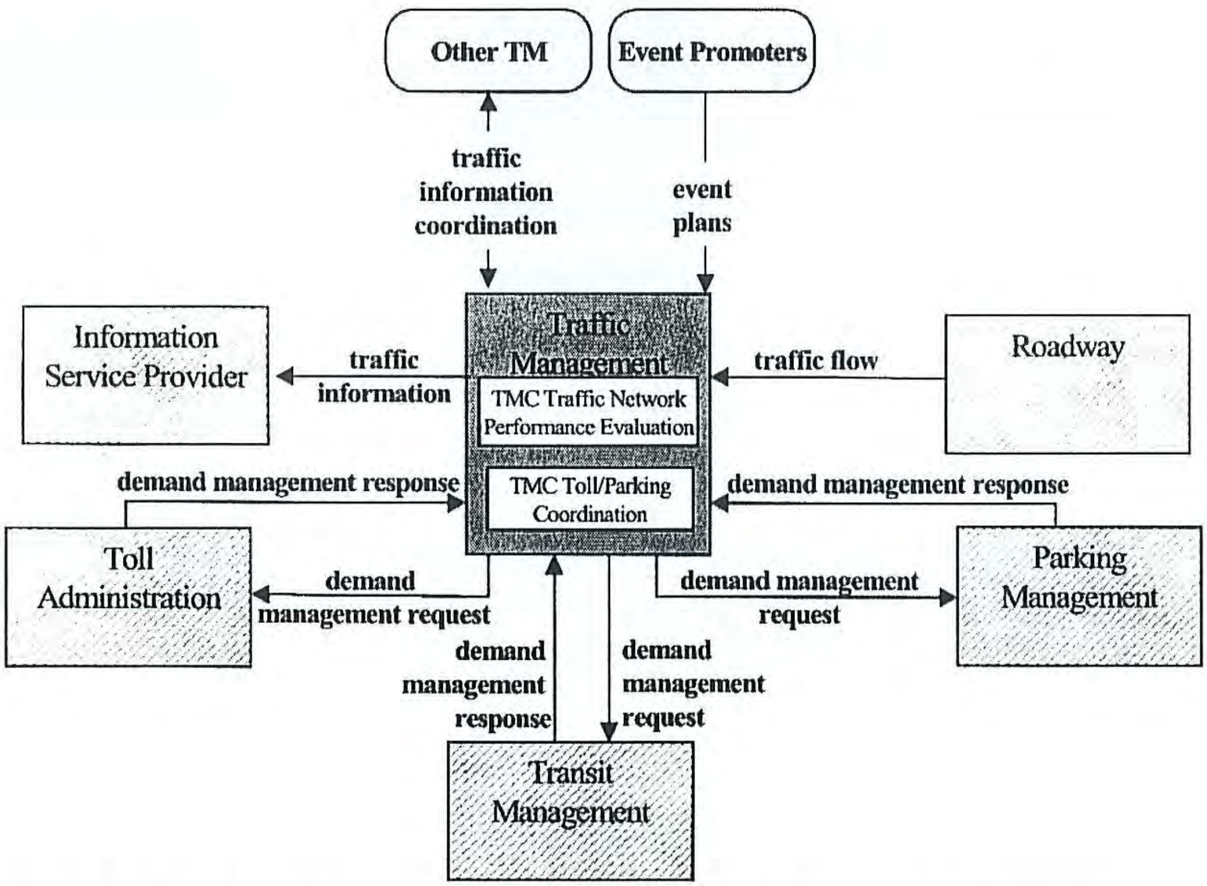
Traffic Management: Traffic Information Dissemination (ATMS6)

This market package allows traffic information to be disseminated to drivers and vehicles using roadway equipment such as dynamic message signs or highway advisory radio. This package provides a tool that can be used to notify drivers of incidents; careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package also covers the equipment and interfaces that provide traffic information from a traffic management center to the media (for instance via a direct tie-in between a traffic management center and radio or television station computer systems), transit management center, emergency management center, and information service provider.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

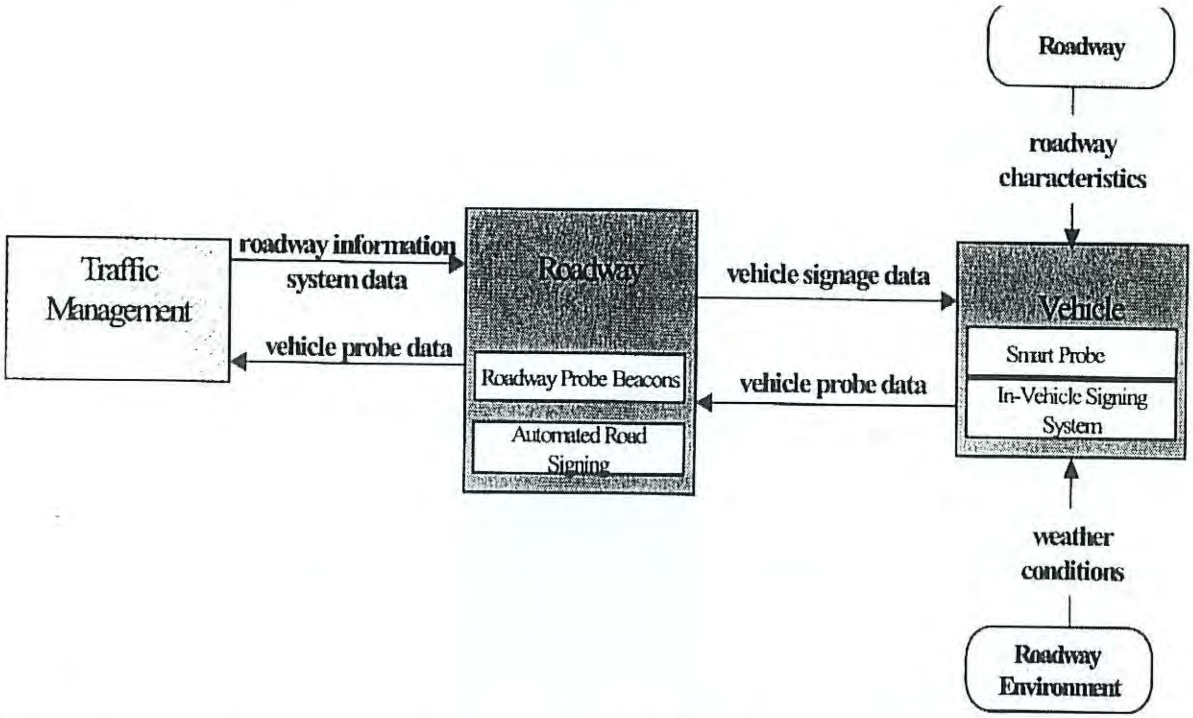
Traffic Management: Traffic Forecast and Demand Management (ATMS9)
This market package includes advanced algorithms, processing, and mass storage capabilities that support historical evaluation, real-time assessment, and forecast of the roadway network performance. This includes the prediction of travel demand patterns to support better link travel time forecasts. The source data would come from the Traffic Management Subsystem itself as well as other traffic management centers and predicted traffic loads derived from route plans supplied by the Information Service Provider Subsystem. In addition to short term forecasts, this market package provides longer range forecasts that can be used in transportation planning. This market package provides data that supports the implementation of Travel Demand Management (TDM) programs, and policies managing both traffic and the environment. Information on vehicle pollution levels, parking availability, usage levels, and vehicle occupancy are collected by monitoring sensors to support these functions. Demand management requests can also be made to Toll Administration, Transit Management, and Parking Management Subsystems.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

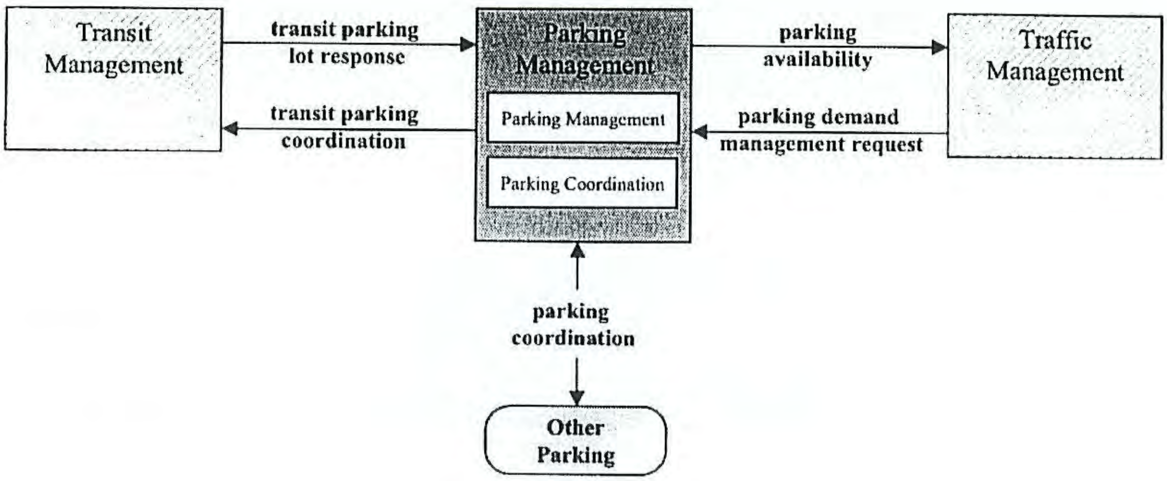
Traffic Management: Virtual TMC and Smart Probe Data (ATMS12)

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



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.
In-Vehicle Signing

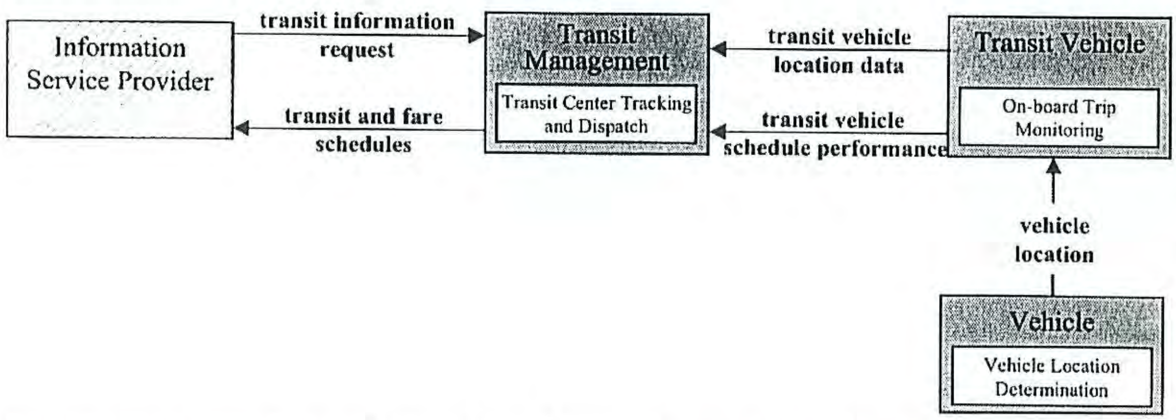
Traffic Management: Regional Parking Management (ATMS19)
This market package supports coordination between parking facilities to enable regional parking management strategies.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

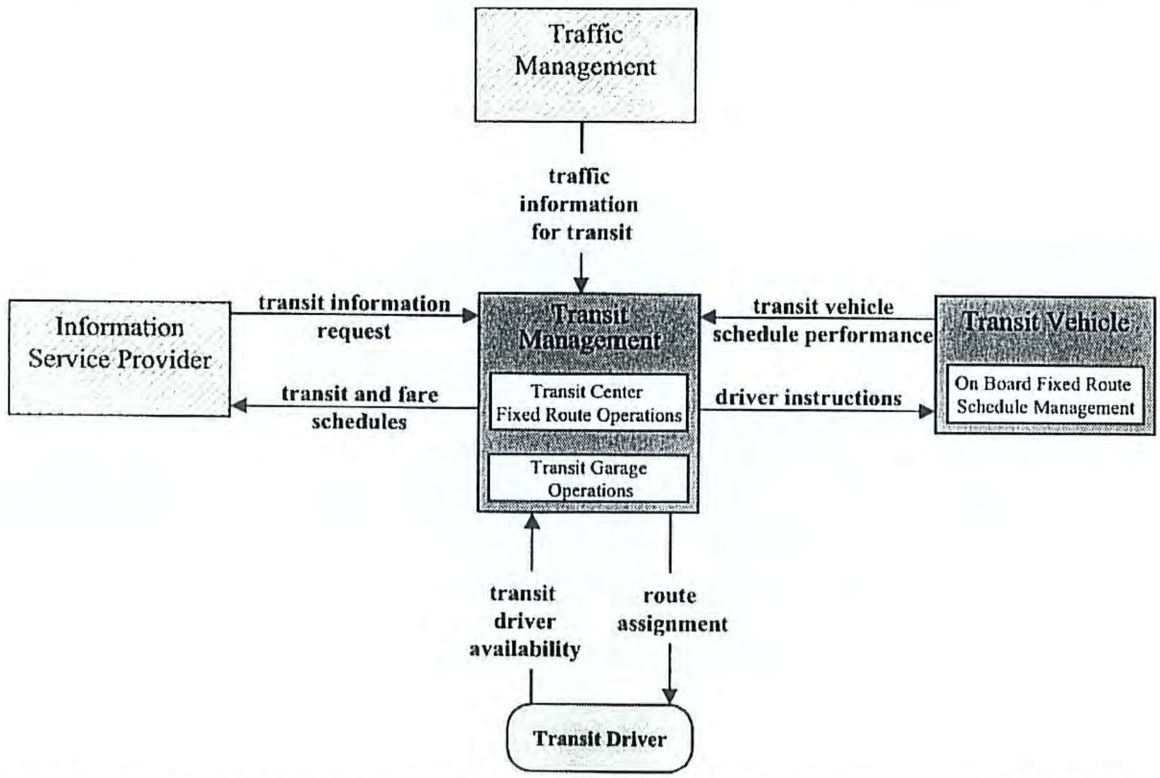
Public Transportation: Transit Vehicle Tracking (APTS1)

This market package provides for an Automated Vehicle Location System to track the transit vehicle's real time schedule adherence and updates the transit system's schedule in real-time. Vehicle position may be determined either by the vehicle (e.g., through GPS) and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communication link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule and makes real-time schedule information available to the Information Service Provider Subsystem via a wireline link.



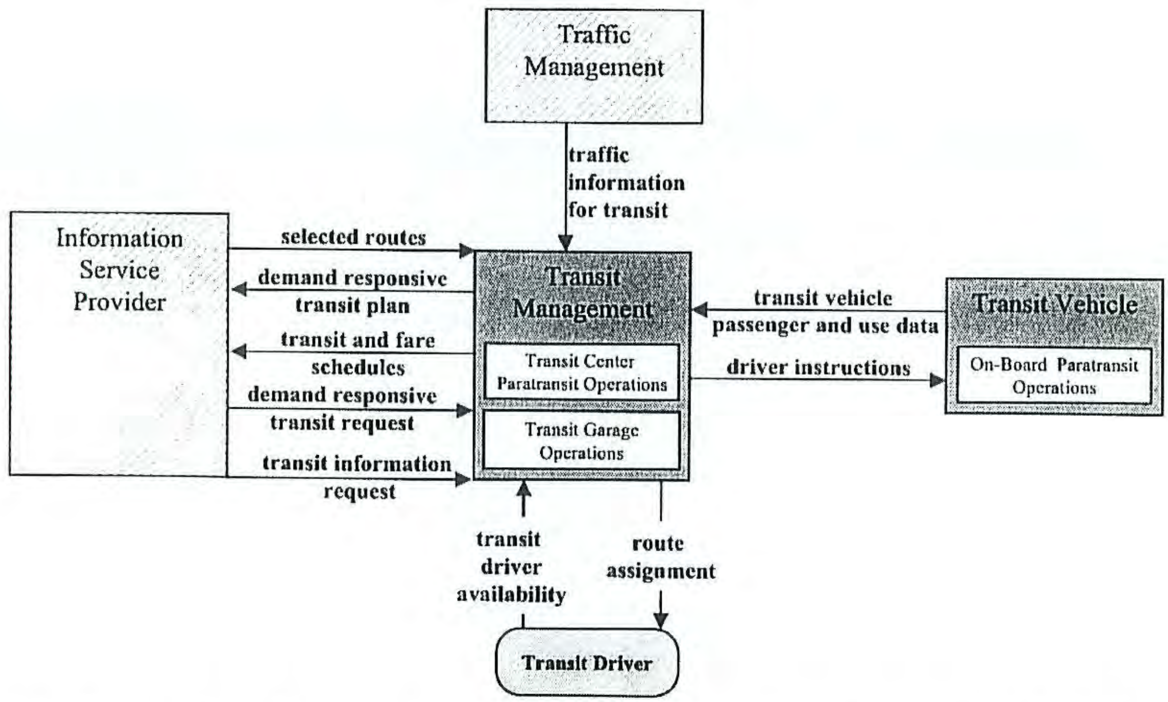
*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

Public Transportation: Transit Fixed-Route Operations (APTS2)
This market package performs automatic driver assignment and monitoring, as well as vehicle routing and scheduling for fixed-route services. This service uses the existing AVL database as a source for current schedule performance data, and is implemented through data processing and information display at the transit management subsystem. This data is exchanged using the existing wireline link to the information service provider where it is integrated with that from other transportation modes (e.g. rail, ferry, air) to provide the public with integrated and personalized dynamic schedules



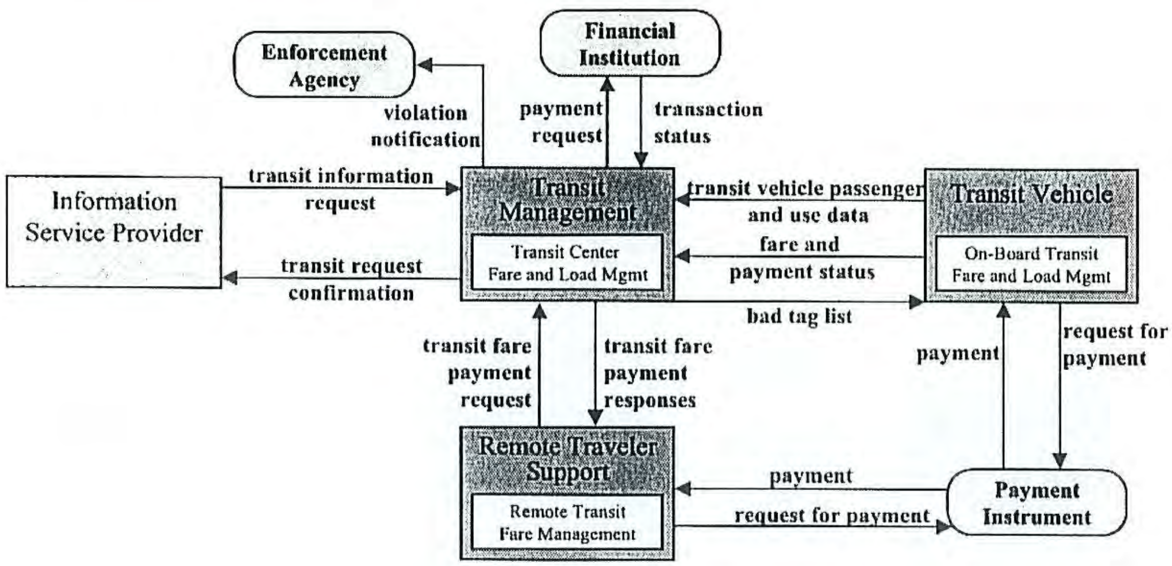
*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

Public Transportation: Demand Response Transit Operations (APTS3)
This market package performs automatic driver assignment and monitoring as well as vehicle routing and scheduling for demand response transit services. This package uses the existing AVL database to monitor current status of the transit fleet and supports allocation of these fleet resources to service incoming requests for transit service while also considering traffic conditions. The Transit Management Subsystem provides the necessary data processing and information display to assist the transit operator in making optimal use of the transit fleet. The Information Service Provider Subsystem may be either be operated by transit management center or be independently owned and operated by a separate service provider. In the first scenario, the traveler makes a direct request to a specific paratransit service. In the second scenario, a third party service provider determines the paratransit service is a viable means of satisfying a traveler request and uses wireline communications to make a reservation for the traveler.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

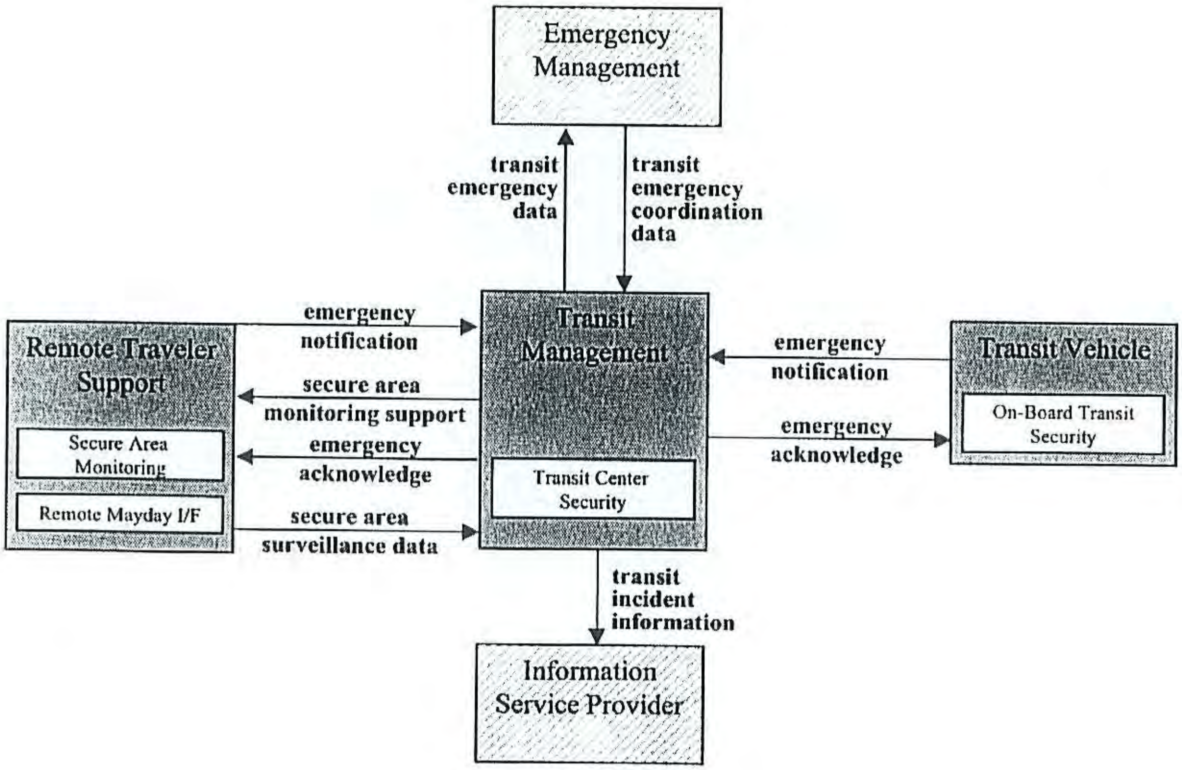
Public Transportation: Transit Passenger and Fare Management (APTS4)
This market package allows for the management of passenger loading and fare payments onboard vehicles using electronic means. The payment instrument may be either a stored value or credit card. This package is implemented with sensors mounted on the vehicle to permit the driver and central operations to determine vehicle loads, and readers located either in the infrastructure or on-board the transit vehicle to allow fare payment. Data is processed, stored, and displayed on the transit vehicle and communicated as needed to the Transit Management Subsystem using existing wireless infrastructure.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

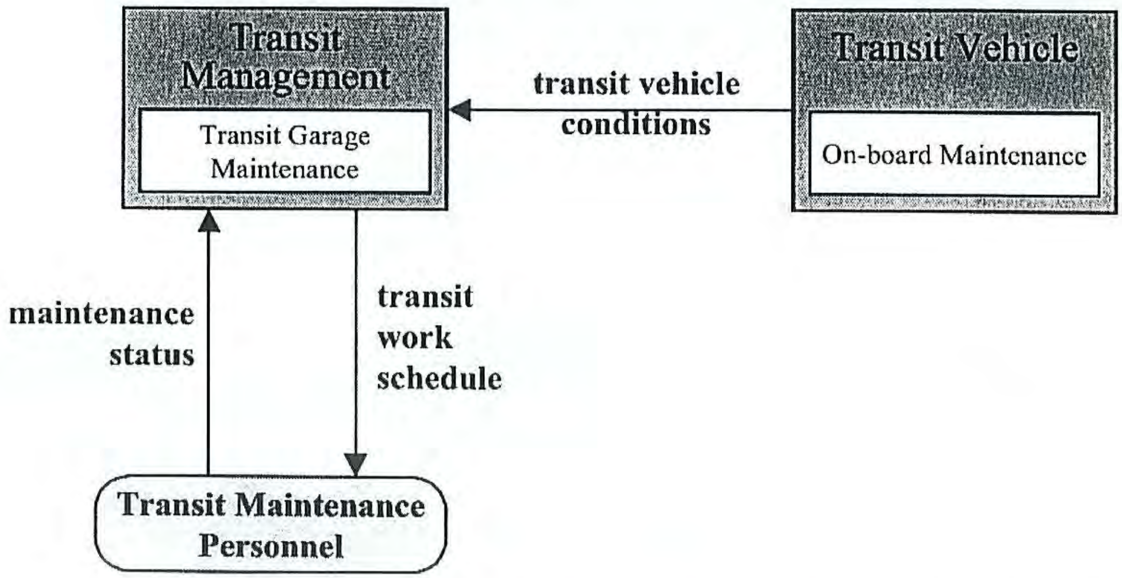
Public Transportation: Transit Security (APTS5)

This market package provides for the physical security of transit passengers. An on-board security system is deployed to perform surveillance and warn of potentially hazardous situations. Public areas (e.g. stops, park and ride lots, stations) are also monitored. Information is communicated to the Transit Management Subsystem using the existing or emerging wireless (vehicle to center) or wireline (area to center) infrastructure. Security related information is also transmitted to the Emergency Management Subsystem when an emergency is identified that requires an external response. Incident information is communicated to the Information Service Provider.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

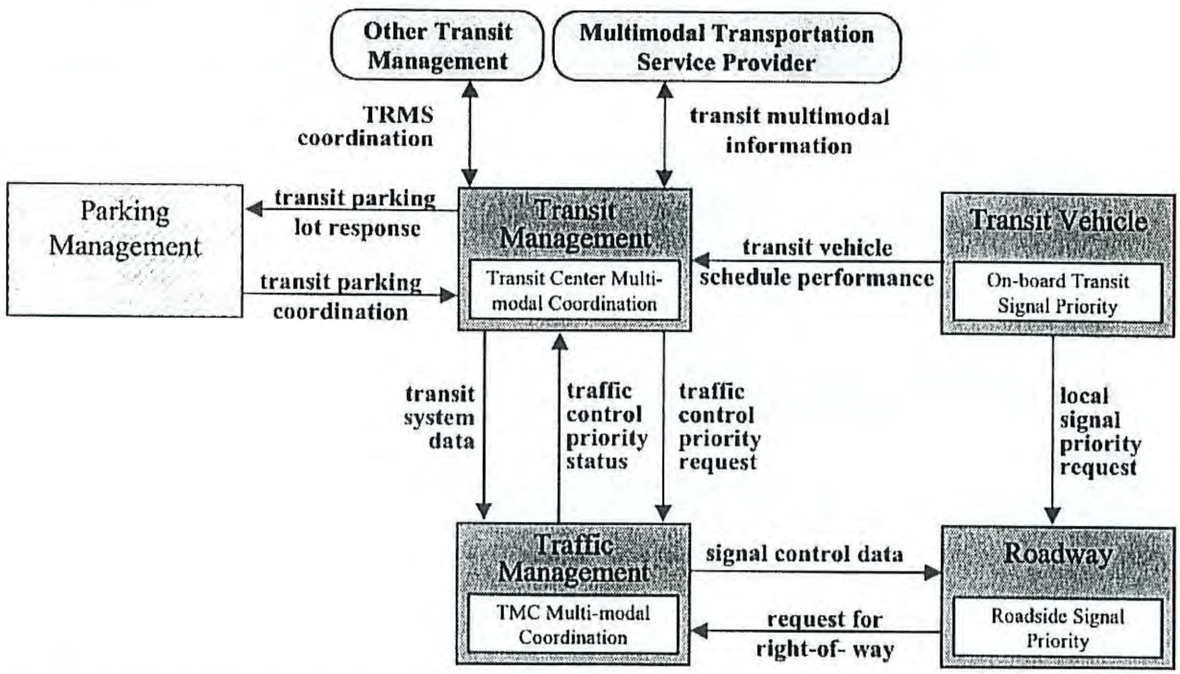
Public Transportation: Transit Maintenance (APTS6)
This market package supports automatic maintenance scheduling and monitoring. On-board condition sensors monitor critical system status and transmit critical status information to the Transit Management Subsystem. Hardware and software in the Transit Management Subsystem processes this data and schedules maintenance activities.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

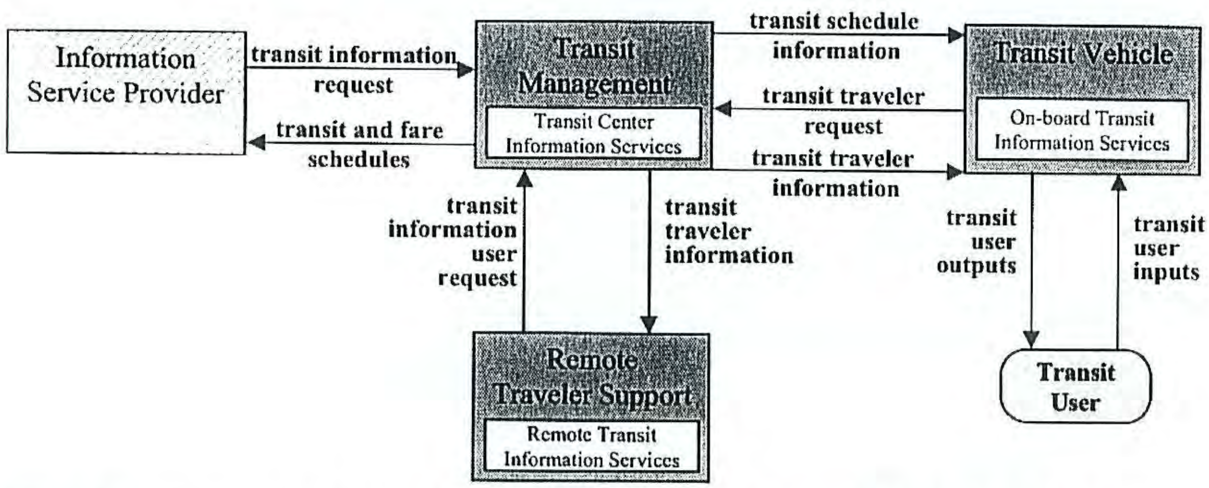
Public Transportation: Multi-modal Coordination (APTS7)

This market package establishes two way communications between multiple transit and traffic agencies to improve service coordination. Intermodal coordination between transit agencies can increase traveler convenience at transfer points and also improve operating efficiency. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network. More limited local coordination between the transit vehicle and the individual intersection for signal priority is also supported by this package.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

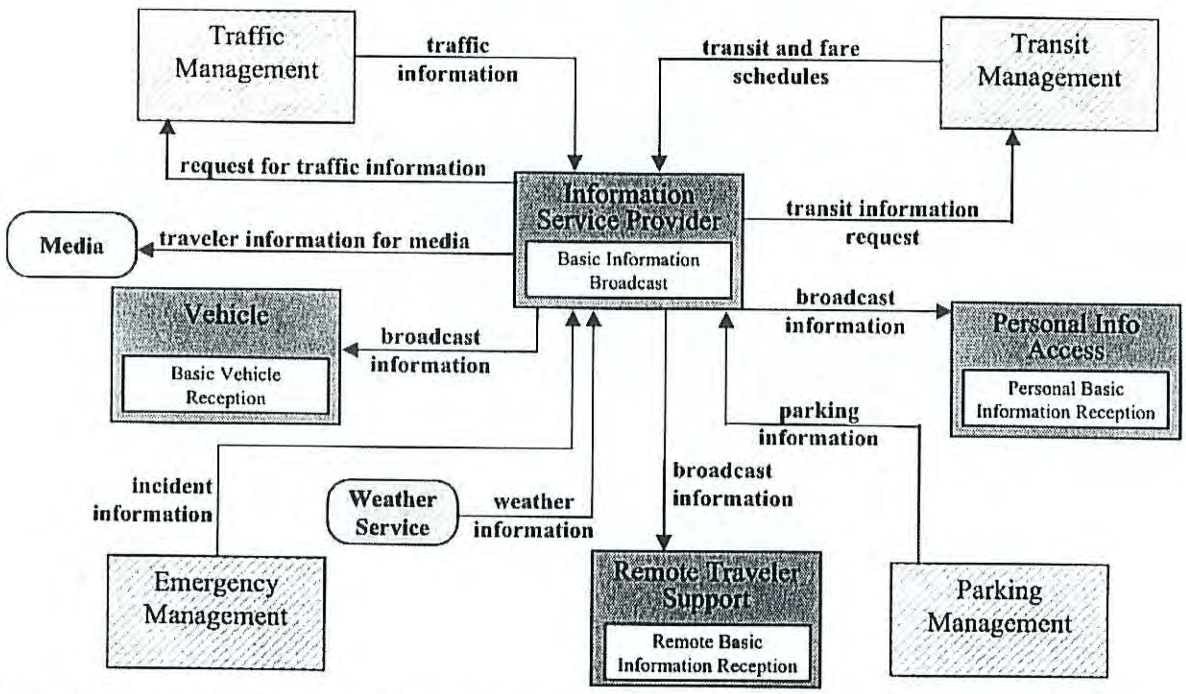
Public Transportation: Transit Traveler Information (APTS8)
This market package provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this market package.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

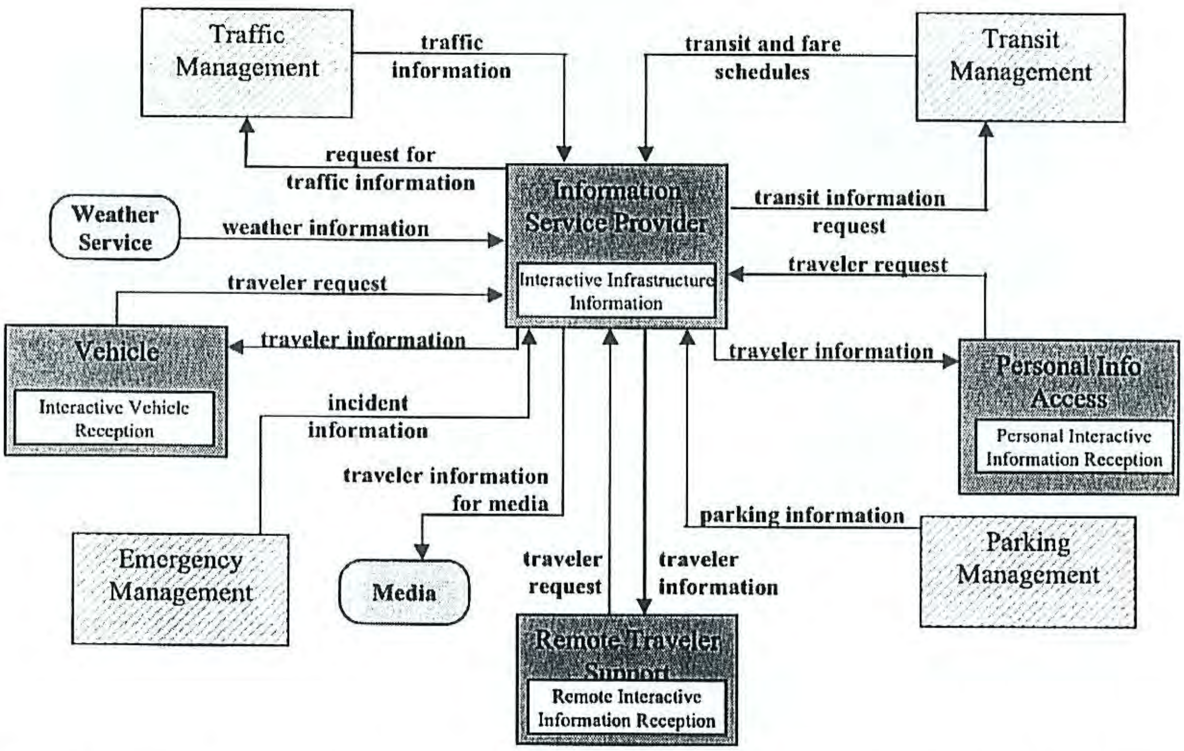
Traveler Information: Broadcast Traveler Information (ATIS1)

This market package provides the user with a basic set of ATIS services; its objective is early acceptance. It involves the collection of traffic conditions, advisories, general public transportation, toll and parking information, incident information, air quality and weather information, and the near real time dissemination of this information over a wide area through existing infrastructures and low cost user equipment (e.g., FM subcarrier, cellular data broadcast). Different from the market package ATMS6--Traffic Information Dissemination--which provides the more basic HAR and DMS information capabilities, ATIS1 provides the more sophisticated digital broadcast service. Successful deployment of this market package relies on availability of real-time traveler information from roadway instrumentation, probe vehicles or other sources.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

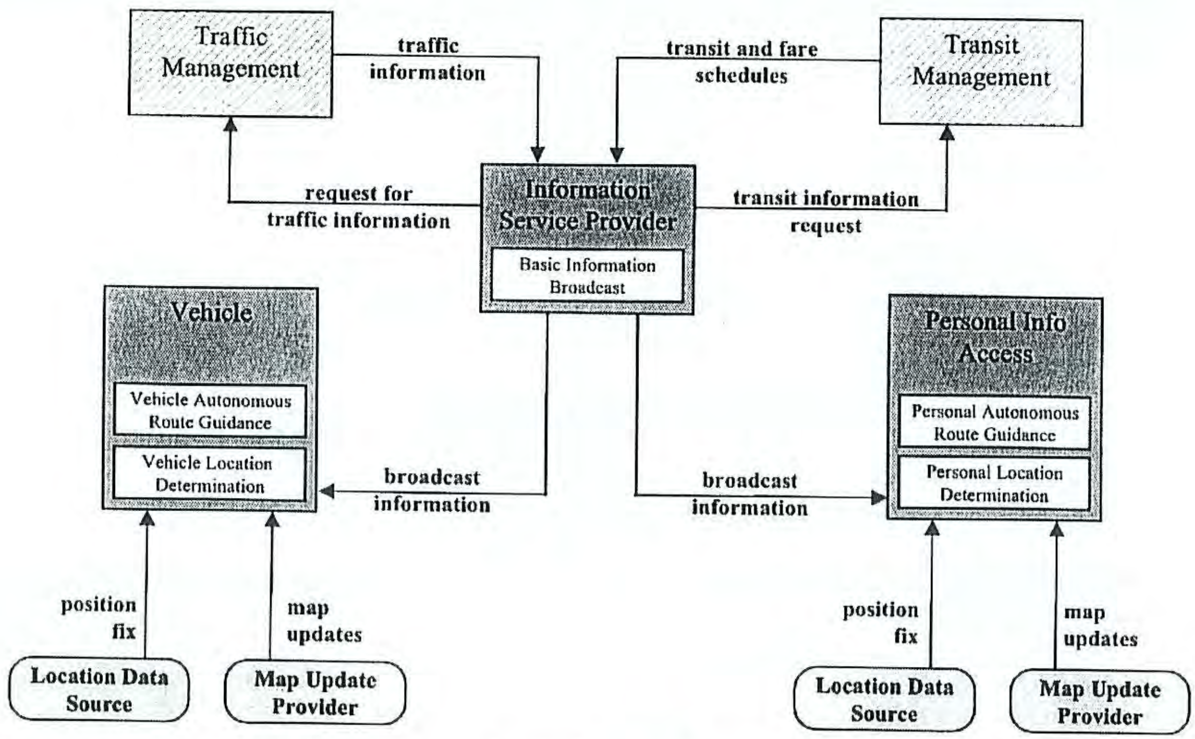
Traveler Information: Interactive Traveler Information (ATIS2)
This market package provides tailored information in response to a traveler request. Both realtime interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on a submitted profile are supported. The traveler can obtain current information regarding traffic conditions, transit services, ride share/ride match, parking management, and pricing information. A range of two-way wide-area wireless and wireline communications systems may be used to support the required digital communications between traveler and the information service provider. A variety of interactive devices may be used by the traveler to access information prior to a trip or en-route to include phone, kiosk, Personal Digital Assistant, personal computer, and a variety of in-vehicle devices. Successful deployment of this market package relies on availability of real-time transportation data from roadway instrumentation, probe vehicles or other means.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

Traveler Information: Dynamic Route Guidance (ATIS4)

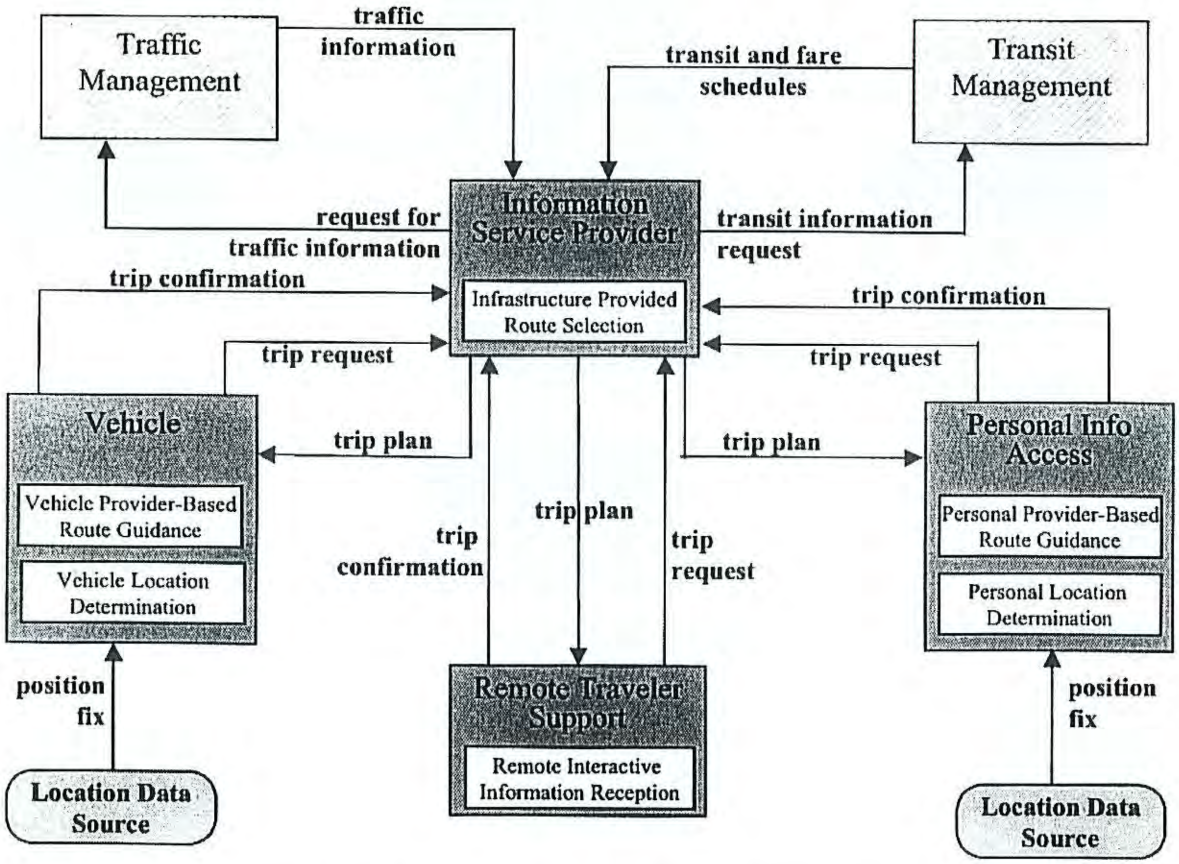
This market package offers the user advanced route planning and guidance which is responsive to current conditions. The package combines the autonomous route guidance user equipment with a digital receiver capable of receiving real-time traffic, transit, and road condition information which is considered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



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

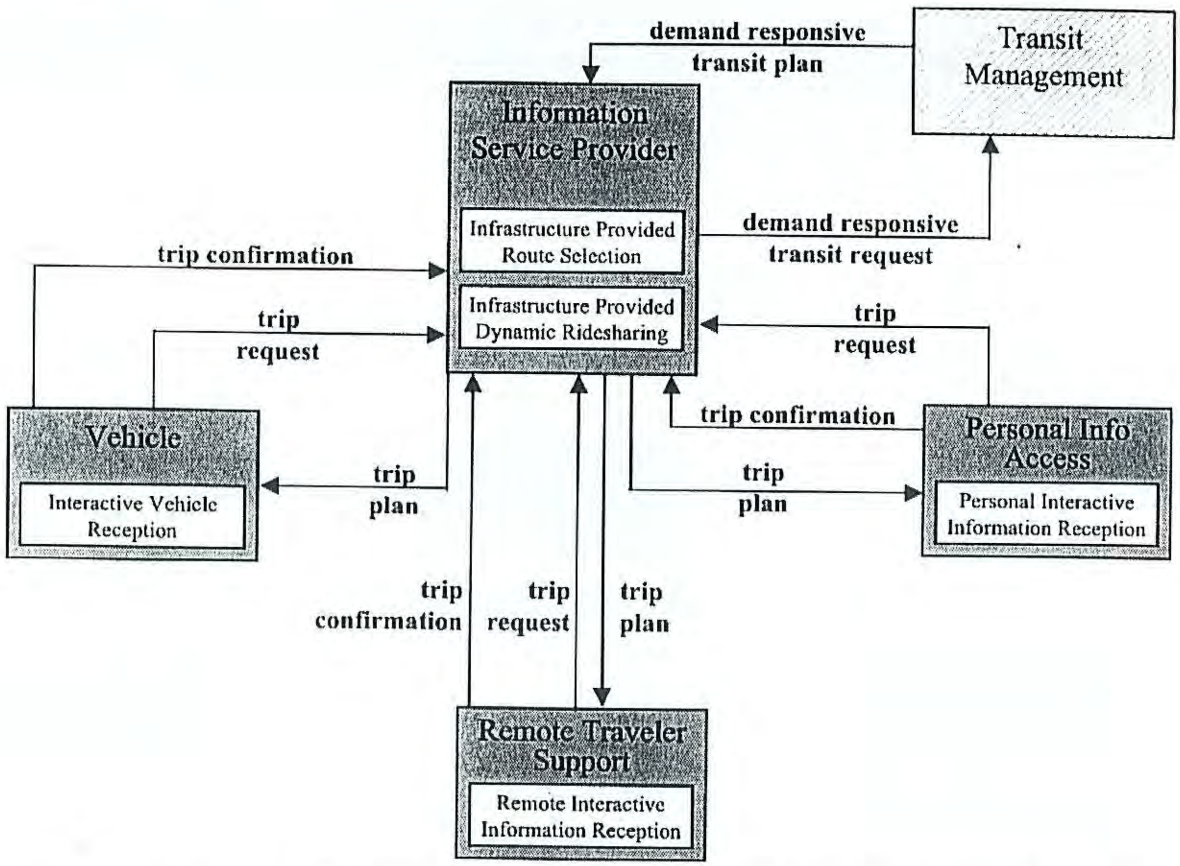
Traveler Information: ISP-Based Route Guidance (ATIS5)

This market package offers the user advanced route planning and guidance which is responsive to current conditions. Different than the Dynamic Route Guidance Market Package, this market package moves the route planning function from the user device to the information service provider. This approach simplifies the user equipment requirements and can provide the infrastructure better information on which to predict future traffic and appropriate control strategies to support basic route planning with minimal user equipment. The package includes both turn by turn route guidance as might be used in a vehicle, as well as pre-trip routes. The package includes two way data communications and optionally also equips the vehicle with the databases, location determination capability, and display technology to support turn by turn route guidance.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

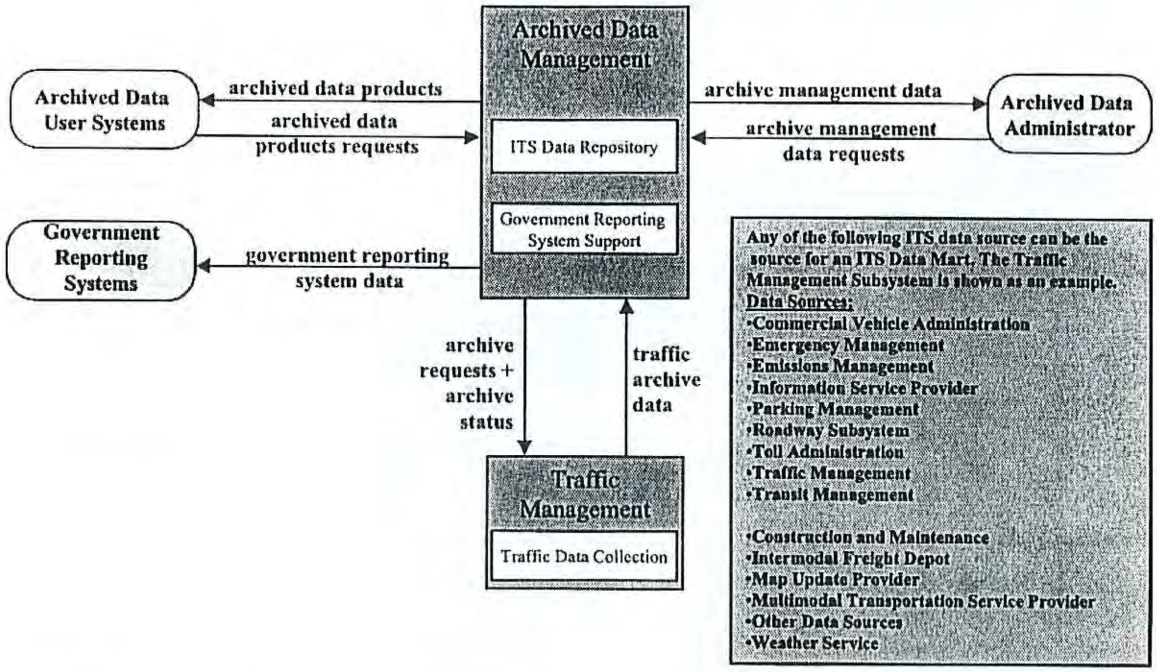
Traveler Information: Dynamic Ridesharing (ATIS8)
This market package enhances the Interactive Traveler Information package by adding an infrastructure provided dynamic ridesharing/ride matching capability. In terms of equipment requirements, ATIS8 is similar to ATIS7.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

Archived Data Management: ITS Data Mart (AD1)

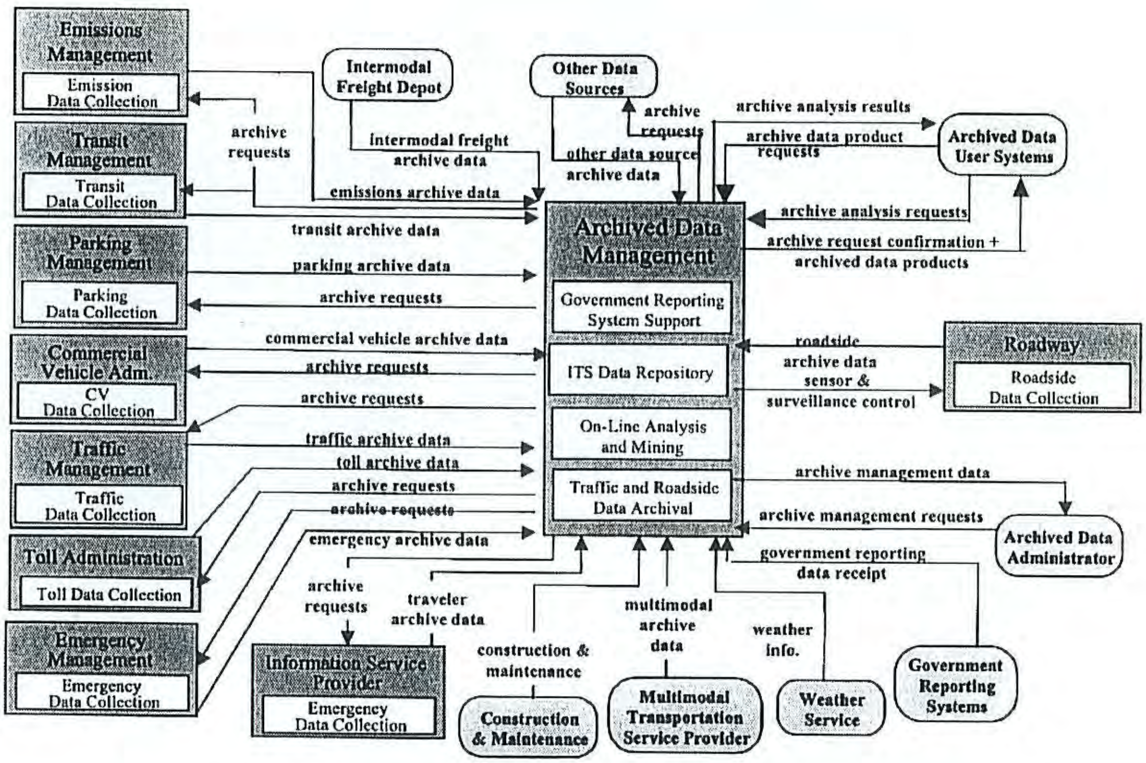
This market package provides a focused archive that houses data collected and owned by a single agency, district, private sector provider, research institution, or other organization. This focused archive typically includes data covering a single transportation mode and one jurisdiction that is collected from an operational data store and archived for future use. It provides the basic data quality, data privacy, and meta data management common to all ITS archives and provides general query and report access to archive data users.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

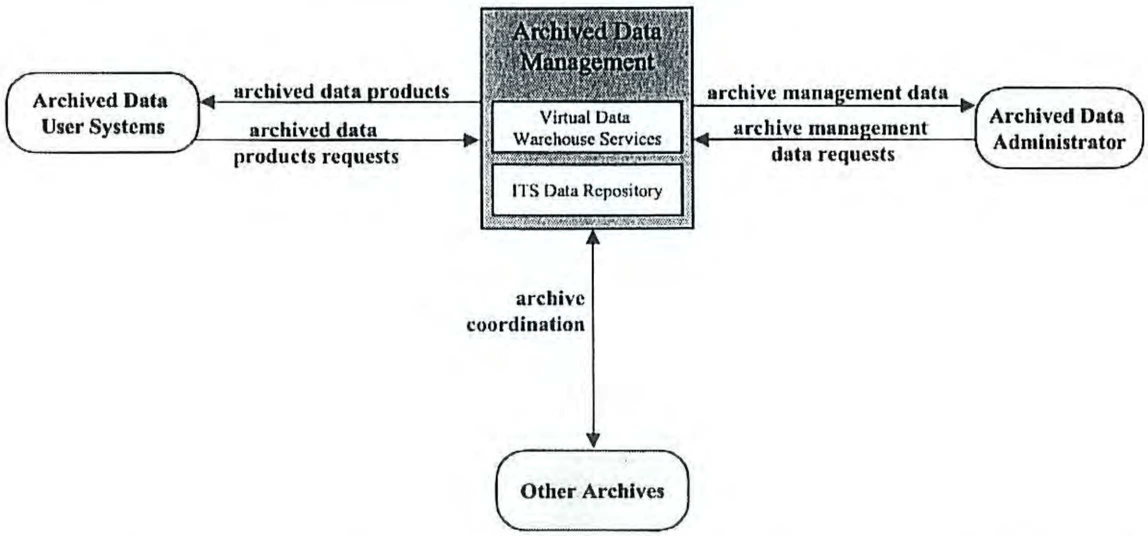
Archived Data Management: ITS Data Warehouse (AD2)

This market package includes all the data collection and management capabilities provided by the ITS Data Mart, and adds the functionality and interface definitions that allow collection of data from multiple agencies and data sources spanning across modal and jurisdictional boundaries. It performs the additional transformations and provides the additional meta data management features that are necessary so that all this data can be managed in a single repository with consistent formats. The potential for large volumes of varied data suggests additional online analysis and data mining features that are also included in this market package in addition to the basic query and reporting user access features offered by the ITS Data Mart.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

Archived Data Management: ITS Virtual Data Warehouse (AD3)
This market package provides the same broad access to multi-modal, multidimensional data from varied data sources as in the ITS Data Warehouse market package, but provides this access using enhanced interoperability between physically distributed ITS archives that are each locally managed. Requests for data that are satisfied by access to a single repository in the ITS Data Warehouse market package are parsed by the local archive and dynamically translated to requests to remote archives which relay the data necessary to satisfy the request.



*Note: Graphic shows key market package elements. Some elements are omitted for clarity.

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