Economic and Policy Considerations of Advanced Public Transportation Systems (Apts): Background and Review of Evaluation Approaches

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ECONOMIC AND POLICY CONSIDERATIONS OF ADVANCED PUBLIC TRANSPORTATION SYSTEMS (APTS)

Background and Review of Evaluation Approaches

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This report provides documentation of APTS technologies and reviews the approaches used in evaluation. The IVHS (ITS) literature concerning evaluation of operational tests, shows that evaluation plans generally consist of two components: measures of effectiveness (MOEs) and an evaluation methodology.

Various lessons have been learned from this research effort. These lessons highlight the need for modifications in the approaches that are represented in this research. Modifications that will improve the accuracy, reliability, and usefulness of these approaches are encouraged. Perhaps the most significant lesson learned from this research effort is the need for further development in the area of subjective evaluation or Cost-Benefit Analysis (CBA).
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Foreword

The development of the National Urban Transit Institute (NUTI), a consortium of Florida Agricultural and Mechanical University (FAMU), Florida International University (FIU), Florida State University (FSU), and University of South Florida (USF) headquartered at USF’s Center for Urban Transportation Research (CUTR), has created research opportunities for the Institute’s grantees. One such research opportunity is in the area of Intelligent Vehicle Highway Systems (IVHS), now referred to as Intelligent Transportation Systems (ITS), and how these technologies influence the operation of fixed-route and demand responsive transit systems.

One of the activities in the NUTI research program is a review of the Economic and Policy Considerations of IVHS (ITS) Transit Applications. CUTR prepared this document report to increase the knowledge and understanding of IVHS (ITS) and the application of these technologies to transit. This document will also provide a review of the various activities that are being employed to evaluate Advanced Public Transportation Systems (APTS), and assess how traditional evaluation approaches can be applied to APTS investments. Based on lessons learned in this document, CUTR will develop specific guidelines for the evaluation of APTS projects with other transit investments. These guidelines will be presented in a companion report.

The information assembled in this study will give transit properties assistance in evaluating the cost effectiveness of various APTS applications and weigh the benefits of these investments against other service and facility investments.
Acknowledgments

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Abstract

Advanced Public Transit Systems (APTS) are advanced navigation and communication technologies that are used in all aspects of public transportation. These include the application of advanced electronic technologies to the deployment and operation of high occupancy, shared-ride vehicles, conventional buses, rail vehicles, and the entire range of para-transit vehicles. Three basic APTS subsystems are available for deployment in support of transit travelers and operations. These include Smart Traveler technology, Smart Vehicle technology, and Smart Intermodal Systems.

This report provides documentation of APTS technologies and reviews the approaches used in evaluation. The IVHS (ITS) literature concerning evaluation of operational tests, shows that evaluation plans generally consist of two components: measures of effectiveness (MOEs) and an evaluation methodology.

Various lessons have been learned from this research effort. These lessons highlight the need for modifications in the approaches that are represented in this research. Modifications that will improve the accuracy, reliability, and usefulness of these approaches are encouraged. Perhaps the most significant lesson learned from this research effort is the need for further development in the area of subjective evaluation or Cost-Benefit Analysis (CBA).
Executive Summary

The term IVHS (ITS) is used to describe projects which apply advanced technologies and communication systems to improve the efficiency and capacity of transportation systems. The growth and interest in IVHS (ITS) applications as an element of a transportation system have been significant in the past several years. While only a few IVHS (ITS) applications have been deployed, several are in operational tests.

Several technologies are included in IVHS (ITS), such as electronics, computer hardware and software, and communications. The Strategic Plan for IVHS in America identified six functional areas in which these technologies are applied. These functional areas are presented below.

- **Advanced Traffic Management Systems (ATMS)** employ innovative technologies and integrate new and existing traffic management and control systems in order to be responsive to dynamic traffic conditions while servicing all modes of transportation.

- **Advanced Traveler Information Systems (ATIS)** acquire, analyze, communicate, and present information to assist surface transportation travelers in moving from a starting location (origin) to their desired destination.

- **Advanced Vehicle Control Systems (AVCS)** combine sensors, computers, and control systems in vehicles and in the infrastructure to warn and assist drivers or to intervene in the driving task.

- **Commercial Vehicle Operations (CVO)** systems apply various IVHS (ITS) technologies to improve the safety and efficiency of commercial vehicle and fleet operations.

- **Advanced Public Transit Systems (APTS)** are advanced navigation and communication technologies that are used in all aspects of public transportation.

The potential for IVHS (ITS) technologies in transit is uncertain and decisions on whether to support the development of various systems require data and careful analysis. The objective of this study is to investigate the economic benefits and costs of APTS applications and to measure the benefits of these investments against other service and facility investments. This first memorandum includes a definition of APTS technologies and a review of the Federal APTS Program and the APTS Technical Committee of IVHS (ITS) America. This is followed by a discussion of the existing APTS applications and the integration of these systems into three technology groups: Smart Traveler, Smart Vehicle, and Smart Intermodal Systems. The
approaches used to evaluate these tests are reviewed and assessed. This document concludes
with a discussion of the lessons learned about APTS technologies.

Advanced Public Transportation Systems (APTS) are advanced navigation and communication
technologies that are used in all aspects of public transportation. These include the application
of advanced electronic technologies to the deployment and operation of high occupancy vehicles,
shared-ride vehicles, conventional buses, rail vehicles, and the entire range of paratransit
vehicles. These systems enable transit agencies to make timely and needed transit information
available to passengers, an element that is important to improving the convenience, reliability,
and safety of public transportation.

The Federal Transit Administration (FTA) established the APTS Program as part of the Federal
Department of Transportation's (USDOT) initiative in IVHS (ITS). While most IVHS (ITS)
systems are designed for highways and the automobile driver, the APTS program addresses this
imbalance by developing technologies that will improve the public transit option; this is consistent
with the goals of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Besides
the USDOT's effort to integrate IVHS (ITS) technologies into current transportation systems, the
Intelligent Vehicle Highway Society of America (IVHS America), an advisory committee to the
USDOT on IVHS (ITS), established the APTS Technical Committee. Coordination,
communication, and information sharing of APTS technologies is provided through this technical
commitee to IVHS America. It is a focal point for discussing program guidelines and candidate
technologies for operational tests. Additionally, the APTS Technical Committee advises the FTA
in areas affecting the APTS program.

Three basic APTS subsystems are available for deployment in support of transit travelers and
operations.

- **Smart Traveler** is the use of traveler information systems to provide real-time, multi-modal
  travel information to users to help en-route or mode choice.

- **Smart Vehicle** in this study refers to the use of Automatic Vehicle Location (AVL) to figure
  out transit vehicle positions in the development of transit fleet management.

- **Smart Intermodal Systems**, also known as the Mobility Manager, strive for coordination
  and integration of transportation services offered by multiple providers.

Operational tests serve as the transition between research and development and full scale
deployment of IVHS (ITS) technologies. The tests permit an evaluation of how well newly
developed technologies perform under real operating conditions. Moreover, they assess the
benefits and public support for the product or system. These tests provide the participating
organizations with a realistic perspective of the potential benefits of IVHS (ITS) without incurring the risks of full deployment. They also provide an opportunity to experiment with various institutional arrangements, to evaluate consumer market reception to various products and services, and to evaluate benefits and costs.

An APTS operational test provides more than a demonstration of the technology. Typically, each test employs the scientific method to gather valid data to use in the national effort to further APTS. The products of the operational test are the data and information gained from the test. It is important, however, to understand that the objective of the evaluation is not to determine the "success" or "failure" of the operational test, but to help support further development of IVHS (ITS) systems, public policy affecting these systems, marketing strategies by vendors, and the decision to make long-term investments in these systems.

A review of IVHS (ITS) literature concerning evaluation of current operational tests, shows that evaluation plans generally consist of five major components: project background and description of APTS application, project goals and objectives, determination of measures of effectiveness (MOEs), selection of evaluation methodology, and an operational test. A brief description of each component is presented below.

- **Project Goals and Objectives** - The primary goal of any operational test should be to evaluate the performance of the technology and its potential impacts on the transportation system.

- **Measures of Effectiveness (MOEs)** - MOEs are associated with specific objectives in the operational test (i.e., increase in ridership, decrease in operating costs, or improvements in system productivity). This component might include collecting data on selected MOEs. If an empirical evaluation approach is used in the test, the information collected will serve as baseline data.

- **Evaluation methodology** - The evaluation methodology component represents the approach or approaches that are used to assess the performance of the technology and its potential impacts on the transportation system. Some operational tests do not include an evaluation methodology.

- **Data collection and processing** - Analysis of data collected during the performance of the operational test provides an evaluation of the technology and its impacts on the transportation system. In addition, an early analysis of data collected during the test may identify the need for mid-course corrections to the test.
• **Operational test results** - An operational test should culminate in a summary report. This report should include an evaluation of the project in terms of its attainment of project goals and objectives. In addition, this report should provide insight on issues effecting the feasibility of the application being tested, influence of site-specific attributes and external factors on the results of the test, and lessons learned.

Measures of effectiveness (MOEs) are selected to provide quantitative measures of the benefits derived from APTS technologies. Quantitative MOEs are expressed in terms of counts, measurements, dollars, or other physical units. In addition, quantitative MOEs show how an APTS system influences a transit system's work force requirements, use of capital equipment, and ridership.

When quantitative MOEs cannot be found and when supplemental measures are needed, qualitative MOEs are employed to evaluate projects. Qualitative MOEs are expressed in terms of people’s attitudes, perceptions, or observations. Qualitative MOEs may include other benefits or impacts associated with the use of APTS. These relate to political and institutional coordination, human factors, and IVHS (ITS) system architecture and standards.

Measures of effectiveness (MOEs) are selected to provide quantitative measures and comparisons of the benefits derived from APTS technologies. Quantitative MOEs are expressed in terms of counts, measurements, dollars, or other physical units. In addition, Quantitative MOEs reflect the influence that APTS may have on a transit system through a reduction in work force requirements, a more efficient use of capital equipment or an increase in ridership. Some of the methodologies that are being employed to evaluate the benefits of APTS include technical, empirical, model-based evaluations, and cost-benefit analysis. A technical approach is used to assess the functionality of the system being tested. Empirical evaluation uses data collected on selected MOEs during the operational test. Models are used to simulate the potential benefits and impacts of APTS. Benefit-cost analysis (BCA) assesses the benefits of the system and are compared with the cost.

Besides the approaches that are presented in this research, guidelines for performing evaluations on operational test are being developed by The Volpe National Transportation Systems Center (VNTSC). These guidelines provide a common framework and methodology for evaluating individual operational tests. Studies have also been completed on the benefits and costs of IVHS (ITS) technologies and strategies. These studies are analyzed in a document entitled *Analysis of IVHS Benefits/Costs Studies* (Volpe National Transportation Systems Center, 1993).

Various lessons have been learned from this research effort. These lessons highlight the need for modifications in the approaches that are represented in this research. Modifications that will
improve the accuracy, reliability, and usefulness of these approaches are encouraged. For example, a standard automated data collection and reporting technique should be developed. The primary benefit of improved evaluation is that it would produce data that are consistent and reliable, especially for tests involving empirical data. It would also allow comparisons between transit systems for similar operational tests.

Perhaps the most significant lesson learned from this research effort is the need for further development in the area of subjective evaluation or CBA. The review of APTS applications in the U.S. revealed very few efforts to evaluate these projects through CBA. For some projects, a CBA is not included. In most tests, this analysis is planned as the final step in the project evaluation, after a field test has been completed and potential benefits have been reported.

Guidelines on performing evaluation of APTS are already being developed by the VNTSC. Notwithstanding these guidelines, specific guidelines are needed on evaluation of APTS projects using CBA.

In the companion report, guidelines will be established and recommended for evaluating APTS investments. This includes providing methodologies for determining if an APTS investment is feasible and monitoring APTS projects currently being tested. To the extent possible, evaluation approaches will be recommended for different types of APTS investments. This effort will also assess the cost effectiveness of APTS investments as compared to traditional public transportation investments.
I. Introduction

The term IVHS (ITS) is used to describe projects which apply advanced technologies and communication systems to improve the efficiency and capacity of transportation systems. The growth and interest in IVHS (ITS) applications as an element of a transportation system have been significant in the past several years. While only a few IVHS (ITS) applications have been deployed, several are in operational tests.

Several technologies are included in IVHS (ITS), such as electronics, computer hardware and software, and communications. The Strategic Plan for IVHS in America identified six functional areas in which these technologies are applied.¹ These are:

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Advanced Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)
- Advanced Rural Transportation Systems (ARTS)
- Advanced Public Transportation Systems (APTS)

Advanced Traffic Management Systems (ATMS) employ innovative technologies and integrate new and existing traffic management and control systems in order to be responsive to dynamic traffic conditions while servicing all modes of transportation. ATMS technologies include:

- Traffic control centers in major metropolitan areas to gather and report traffic information, and to control traffic movement to enhance mobility and reduce congestion through ramp, signal, and lane management, vehicle route diversion, etc.
- Changeable message signs which provide current information on traffic conditions to highway users, and suggest alternate routes
- Priority control systems to provide safe travel for emergency vehicles when needed

Advanced Traveler Information Systems (ATIS) acquire, analyze, communicate, and present information to assist surface transportation travelers in moving from a starting location (origin) to their desired destination. Technologies include:

- On-board displays of maps and roadway signs (in-vehicle signing)
- On-board navigation and route guidance systems
- Trip planning services

Advanced Vehicle Control Systems (AVCS) combine sensors, computers, and control systems in vehicles and in the infrastructure to warn and assist drivers or to intervene in the driving task. AVCS technologies include:

- Adaptive cruise control (which slows a cruise-controlled vehicle if it gets too close to a preceding vehicle)
- Automatic collision avoidance system (automatic braking upon obstacle detection)
- Vehicle platooning (automatically controlling several closely-spaced vehicles in a special highway lane, to increase lane capacity)

Commercial Vehicle Operations (CVO) systems apply various IVHS (ITS) technologies to improve the safety and efficiency of commercial vehicle and fleet operations. Example of these technologies include:

- Weigh in motion (WIM)
- Electronic placarding/bill of lading
- Automatic vehicle identification (AVI)

Advanced Rural Transportation Systems (ARTS) addresses applications of IVHS (ITS) technologies to rural needs. IVHS (ITS) applications in rural areas are different than in urban areas, even when services are similar. Rural conditions include low population density, fewer roads, low amount of congestion, sparse or unconventional street addresses, etc. Safety is a significant issue in ARTS; over half of all accidents occur on rural roads. ARTS technologies include:

- Route guidance
- Automatic emergency signaling
- Roadway edge detection

The potential for IVHS (ITS) technologies in transit is uncertain and decisions on whether to support the development of various systems require data and careful analysis. The objective of this study is to investigate the economic benefits and costs of APTS applications and to measure the benefits of these investments against other service and facility investments. This report includes a definition of APTS technologies and a review of the Federal APTS Program and the APTS Technical Committee of IVHS (ITS) America. This is followed by a discussion of the existing APTS applications and the integration of these systems into three technology groups: Smart Traveler, Smart Vehicle, and Smart Intermodal Systems. The approaches used to evaluate these tests are reviewed and assessed. This report concludes with a discussion of the lessons learned about APTS technologies.
II. Advanced Public Transportation Systems (APTS)

Advanced Public Transportation Systems (APTS) are advanced navigation and communication technologies that are used in all aspects of public transportation. These include the application of advanced electronic technologies to the deployment and operation of high occupancy vehicles, shared-ride vehicles, conventional buses, rail vehicles, and the entire range of paratransit vehicles. These systems enable transit agencies to make timely and needed transit information available to passengers, an element that is important to improving the convenience, reliability, and safety of public transportation. For example, smart cards can improve passenger interface with a transit system which can improve the efficiency and attractiveness of public transportation. Smart cards are being tested in various locations of the country. What is most important, APTS will help transit agencies manage a safe and efficient fleet and plan services to satisfy a broad range of consumer needs. When incorporated with a regional transportation system, APTS will also enable a system to manage its roadways with special accommodations for high occupancy vehicles.

Federal APTS Program

The Federal Transit Administration (FTA) established the APTS Program as part of the Federal Department of Transportation's (USDOT) initiative in IVHS (ITS). While most IVHS (ITS) systems are designed for highways and the automobile driver, the APTS program addresses this imbalance by developing technologies that will improve the public transit option; this is consistent with the goals of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The APTS Program is structured to undertake research and development of advanced navigation, information, and communication systems. Through APTS, FTA supports (by funding operational test projects) and coordinates the development of these technologies for both transit and ride sharing. Figure 1 illustrates the coordination of the APTS program within USDOT.

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2A smart card is an integrated circuit card that contains both memory and a microprocessor. It is capable of receiving, storing, and processing information. In the context of APTS, it is used as a debit card for mass transit.
Figure 1
APTS program within USDOT

USDOT

FBWA  NHTSA  FTA  OST  RSPA

IVHS

AVCS  APTS

ATMS  ATIS  CVO

Federal Highway Administration (FHWA)
National Highway Traffic Safety Administration (NHTSA)
Federal Transit Administration (FTA)
Office of the Secretary (OST)
Research and Special Programs Administration (RSPA)

Note: This represents IVHS participation only.
The goal of the APTS Program is to:

Enhance the ability of public transportation systems to satisfy customer needs and contribute to community goals by providing information on innovative applications of IVHS technologies from a coordinated operational test and evaluation program.¹

This goal statement is further supported by four objectives.

**Objective #1:** Enhance the quality of on-street service to customers. This objective puts emphasis on making public transit user-friendly by improving the quality, timeliness, and availability of passenger information, increasing the convenience of fare payments, improving safety and security, and service reliability, reducing travel time, and increasing opportunities for customer responses.

**Objective #2:** Improve system productivity and job satisfaction. The emphasis of this objective is on making public transit more efficient through improvements in schedule adherence and incident response, service planning and scheduling, and response to vehicle and facility failures. This objective also focuses on improvements to information management systems and practices, reducing worker stress, and providing job enrichment for employees.

**Objective #3:** Enhance the contribution of public transportation systems to overall community goals. The focus of this objective is to increase the utilization of public transportation by providing conveniences to special user groups (i.e., visual or hearing impaired) and communicating these services to passengers. Increasing the effectiveness of Transportation Demand Management programs (TDM) is also an element of this objective.

**Objective #4:** Expand the knowledge base of professionals concerned with APTS innovations. The focus of this objective is on dissemination of information on APTS projects through evaluations of operational tests, information sharing of successful operational tests, and assisting in system design and integration.

By establishing this policy statement and objectives, FTA is attempting to develop an APTS program that highlights the customer and not the transit system or technology.

¹Minutes of the APTS Committee Meeting, (April 13, 1993).
Intelligent Vehicle Highway Society of America's
APTS Technical Committee

Besides the USDOT's effort to integrate IVHS (ITS) technologies into current transportation systems, the Intelligent Vehicle Highway Society of America (IVHS America), an advisory committee to the USDOT on IVHS (ITS), established the APTS Technical Committee. Coordination, communication, and information sharing of APTS technologies is provided through this technical committee to IVHS America. It is a focal point for discussing program guidelines and candidate technologies for operational tests. Additionally, the APTS Technical Committee advises the FTA in areas affecting the APTS program. The Committee also gives guidance on new technologies relating to APTS and distributes information on efforts to increase the use of high-occupancy travel modes. Membership on this committee includes individuals from the transit community, the entire IVHS (ITS) community, representatives from the public sector, private industry, and academia.

The objectives of the APTS Technical Committee are presented below.

(1) Articulate policy initiatives. As an advisory committee to the USDOT, the APTS Technical Committee seeks to influence the direction of the IVHS (ITS) Program planning priorities, and work to accomplish the objectives of ISTEA (i.e., improve air quality, conserve energy, improve highway systems, and upgrade public transportation).

(2) Establish a set-aside for major research and demonstration initiatives. The FTA Section 26-Planning and Research Program provides resources for the study, design, and demonstration of APTS technologies. The APTS Technical Committee advocates that discretionary funds within Section 3 resources, be set-aside for specific demonstration initiatives, when particular initiatives require more funding than is available under Section 26.

(3) Create a new mechanism for public/private partnerships. The APTS Technical Committee supports the idea of allowing public transit agencies to solicit projects (operational tests) which include a public/private agreement.

(4) Improve planning. The APTS Technical Committee seeks to make APTS an integral part of highway and transit capital projects.

(5) Maximize use of flexible funding provisions. The APTS Technical Committee seeks to influence transportation decisionmakers to understand that APTS projects are cost-effective ways to reduce congestion and increase air quality. This will make
these projects candidates for flexible funding through the Surface Transportation Program (STP) and the Congestion Mitigation Air Quality Improvement Program (CMAQ).

(6) *Education and Training.* It is the policy of the APTS Technical Committee to educate Metropolitan Planning Organizations (MPOs) and state DOTs concerning the ways that APTS projects can improve metropolitan transportation systems and assist in meeting clean air objectives.

(7) *Outreach & broadened APTS participation.* The APTS Technical Committee, supported by the FTA Staff, solicits and encourages participation from the vendor community, transit agencies, and industry consultants.

The educational and promotional efforts provided in these objectives promotes widescale implementation of APTS projects that will achieve the goals and objectives of IVHS America and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).

To achieve its objectives, the APTS Technical Committee is organized around five task forces. Each task force has a specific mandate to identify, develop, and test APTS functions within its topic area as shown below.

- *Smart Traveler Task Force* reviews issues that relate to transportation information, service payment, and mobility management systems.

- *Smart Vehicle Task Force* focuses on technologies that are on, interface with, or affect, public transportation vehicles.

- *Smart Intermodal System Task Force* is considering the steps needed to get to an integrated, intermodal system that takes advantage of IVHS (ITS) technologies.

- *Technical Standards Task Force* is developing technical standards on the technologies and systems that are used in APTS.

- *Policy Task Force* is involved in defining a vision and direction for the APTS Committee.

Figure 2 illustrates the coordination of the APTS Technical Committee within IVHS America.
Figure 2
APTS Technical Committee

IVHS America

APTS Technical Committee

Smart Traveler Task Force

Smart Vehicle Task Force

Smart Intermodal System Task Force

Technical Standards Task Force

Policy Task Force
III. Technology Groupings

Three basic APTS subsystems are available for deployment in support of transit travelers and operations. These include Smart Traveler technology, Smart Vehicle technology, and Smart Intermodal Systems. These APTS subsystems represent the transfer of technology innovation to public transportation.

Smart Traveler

Smart Traveler is the use of traveler information systems to provide real-time, multi-modal travel information to users to help en-route or mode choice. FTA and FHWA are jointly supporting and testing a variety of traveler information systems to improve the efficiency and cost-effectiveness of auto/truck travel and public transportation (known as Smart Commuter).

The array of Smart Traveler technologies and applications currently available include the following:

- Smart cards
- Telecommunications
- Touch-tone telephones
- Voice synthesis
- Television, radio, cable TV
- Audiotext/videotext
- Dynamic multi-modal database
- Personal Communications Devices
- Interactive video displays
- Integrated fare payment
- Home or work place multimodal information
- Roadside or transit center monitors
- Wayside and on-board bus displays
- Dynamic ridesharing
- Smart kiosks

Smart Vehicle

Smart Vehicle in this study refers to the use of Automatic Vehicle Location (AVL) to figure out transit vehicle positions in the development of transit fleet management. Transit fleet management will improve the overall system efficiency and productivity. Vehicle locations are determined and transmitted to a central dispatch or control center where information can be used to make real-time adjustments to route planning and scheduling. In addition, FTA is supporting joint use of traffic signal preemption, automatic passenger counting, security devices, and vehicle condition monitoring in these projects to achieve greater benefits.
Available technologies and applications include the following:

- Vehicle component sensors
- Automated passenger counters
- Automatic vehicle location
- Data/voice/cellular radio
- Computer aided dispatch
- Smart card readers
- Audiotext/videotext displays
- Geographic information systems
- Route Deviation Transit
- Automated paratransit dispatching
- On-board automatic guidance equipment
- Fleet monitoring and control
- Real-time data collection and analysis
- Centralized dispatching Schedule planning
- Passenger information
- Equipment performance monitoring

**Smart Intermodal Systems**

Smart Intermodal Systems, also known as the Mobility Manager, strive for coordination and integration of transportation services offered by multiple providers. These providers represent a variety of modes and funding sources. Integration is accomplished through electronic technologies (electronic fare media, card readers, computer assisted scheduling and dispatching) that simplify financial and other kinds of transactions. Smart Intermodal Systems also encourages travel behavior techniques (travel demand management, carpool, flex-time) as a way to improve overall mobility.

Smart Intermodal Systems include the following technologies and applications:

- Automatic vehicle identification
- Image processing
- Vehicle guidance systems
- Dynamic multimodal dispatching software
- Integrated adaptive signal timing and traffic management systems
- Traffic signal timing priorities
- Automatic toll collection and HOV verification
- HOV lane access control
- HOV toll lanes
- HOV bypass lances at metered ramps
- HOV parking incentives
- Electronically guided buses
- Transportation management centers
- On-board or on-site alarm activation
- Computer assisted dispatch and control systems
- Real-time information signs
- Integrated fare payment/toll collection/parking fees
- Mobility Manager
- CCTV monitoring of parking lots and transit terminals
IV. Operational Tests

Operational tests serve as the transition between research and development and full scale deployment of IVHS (ITS) technologies. The tests permit an evaluation of how well newly developed technologies perform under real operating conditions. In addition, they assess the benefits and public support for the product or system.

Developing a sound evaluation methodology of the benefits of IVHS (ITS) is the core of the federal IVHS (ITS) program. Before the passage of ISTEA, most of the reports on IVHS (ITS) effectiveness were not based on empirical field data (i.e., operational tests), but model simulations, more basic estimations, and speculation. Several APTS and IVHS (ITS) operational tests were without any evaluation measurements or criteria. As a result, ISTEA requires that operational tests utilizing Federal funds shall "have a written evaluation of the intelligent vehicle-highway systems technologies investigated and of the results of the investigation . . ." A clear mandate is provided to USDOT and other agencies involved in operational tests to take the leadership role in developing an evaluation criteria. Thus, the evaluation is an integral part of each operational test.

Operational field tests serve as the only forum for evaluation of APTS and IVHS (ITS) technologies. There are a variety of local initiatives and APTS operational tests being evaluated across the country. The evaluations cover all three focus areas of the APTS Program: Smart Traveler, Smart Vehicle, Smart Intermodal Systems. The scope and status of these projects are provided in Appendix A.

These tests provide the participating organizations with a realistic perspective of the potentials benefits of IVHS (ITS) without incurring the risks of full deployment. (It is assumed that the agencies involved in testing these technologies will evaluate the economic feasibility of the project, such as a break-even analysis to justify capital investment in an APTS). They also provide an opportunity to experiment with various institutional arrangements, to evaluate consumer market reception to various products and services, and to evaluate benefits and costs.

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"ISTEA of 1991," Title VI: Research. Part B, Section 6055 (3).
V. Overview of Evaluation Process

An APTS operational test provides more than a demonstration of the technology. Typically, each test employs the scientific method to gather valid data to use in the national effort to further APTS. The products of the operational test are the data and information gained from the test. It is important, however, to understand that the objective of the evaluation is not to determine the "success" or "failure" of the operational test, but to help support further development of IVHS (ITS) systems, public policy affecting these systems, marketing strategies by vendors, and the decision to make long-term investments in these systems.

Figure 3 is a flow diagram representing the evaluation process for an APTS operational test. A review of IVHS (ITS) literature concerning evaluation of current operational tests, shows that evaluation plans generally consist of five major components: project background and description of APTS application, project goals and objectives, determination of measures of effectiveness (MOEs), selection of evaluation methodology, and an operational test. A brief description of each component is presented below.

Project Background and Description of APTS Applications

An APTS operational test will consist of one or more of the applications already introduced in the technology groupings section. For example, a test of Smart Traveler technology might include the use of a smart card to facilitate automatic fare collection for passengers using multiple transit systems. Another example could consist of an examination of ways in which mobile communications, such as cellular phones, might make ridesharing (carpooling and vanpooling), more attractive.
Project Goals and Objectives

The primary goal of any operational test should be to evaluate the performance of the technology and its potential impacts on the transportation system. In addition, each APTS operational test is intended to meet the goals of the APTS Program, which are:

1) Enhance the quality of on-street service to customers.
2) Improve system productivity and job satisfaction.
3) Enhance the contribution of APTS to overall Community goals.
4) Expand the knowledge base of professionals concerned with APTS innovations.

Measures of Effectiveness (MOEs)

MOEs are associated with specific objectives in the operational test (i.e., increase in ridership, decrease in operating costs, or improvements in system productivity). This component might include collecting data on selected MOEs. If an empirical evaluation approach is used in the test, the information collected will serve as baseline data. This topic is discussed in more detail in a subsequent section.

Evaluation methodology

The evaluation methodology component represents the approach or approaches that are used to assess the performance of the technology and its potential impacts on the transportation system. Some operational tests do not include an evaluation methodology. A section on this topic is provided later in this report. It includes a description of the evaluation approaches presented in the diagram.

Operational test

The operational test is actual field evaluation or model-based simulation of the technology.

Data collection and processing

Analysis of data collected during the performance of the operational test provides an evaluation of the technology and its impacts on the transportation system. In addition, an early analysis of data collected during the test may identify the need for mid-course corrections to the test. For example, early results might suggest some bias in the baseline data.
Operational test results

An operational test should culminate in a summary report. This report should include an evaluation of the project in terms of its attainment of project goals and objectives. In addition, this report should provide insight on issues effecting the feasibility of the application being tested, influence of site-specific attributes and external factors on the results of the test, and lessons learned.
VI. Measures of Effectiveness (MOEs)

Measures of effectiveness (MOEs) are selected to provide quantitative measures of the benefits derived from APTS technologies. Quantitative MOEs are expressed in terms of counts, measurements, dollars, or other physical units. In addition, quantitative MOEs show how an APTS system influences a transit system's work force requirements, use of capital equipment, and ridership.

A sample of the quantitative MOEs that are used to assess the performance of APTS is summarized in Table 1.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>MOEs</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Benefits</td>
<td>Travel Time</td>
<td>Reduced vehicle trips</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>Accident prevention</td>
</tr>
<tr>
<td></td>
<td>Comfort and Convenience</td>
<td>Customer interface</td>
</tr>
<tr>
<td></td>
<td>Security</td>
<td>Emergency response</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>Integrated fare payment</td>
</tr>
<tr>
<td>Economic Benefits</td>
<td>Productivity</td>
<td>Decreased cost and increased revenue</td>
</tr>
<tr>
<td></td>
<td>Product Innovation</td>
<td>Real-time rideshare trip matching</td>
</tr>
<tr>
<td></td>
<td>On-time Delivery</td>
<td>Automated dispatching</td>
</tr>
<tr>
<td>Environmental</td>
<td>Air Pollution</td>
<td>Reduced emissions</td>
</tr>
<tr>
<td>Benefits</td>
<td>Fuel usage</td>
<td>Reduce congestion, vehicle trips, and travel</td>
</tr>
<tr>
<td>Information</td>
<td>Trip Efficiency</td>
<td>Improved pre-trip planning</td>
</tr>
<tr>
<td>Benefits</td>
<td>Traffic</td>
<td>Traffic signal preferential treatment</td>
</tr>
<tr>
<td></td>
<td>Enforcement</td>
<td>Improvements to satisfy ADA and Clean Air Act</td>
</tr>
</tbody>
</table>

When quantitative MOEs cannot be found and when supplemental measures are needed, qualitative MOEs are employed to evaluate projects. Qualitative MOEs are expressed in terms of people's attitudes, perceptions, or observations. An example of these include physical attractiveness of the systems components (i.e., automated kiosks designed in Art De'co) and acceptance of the solution by the population it is intended to serve. Qualitative

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MOEs are also included because APTS provide benefits to a variety of groups in a variety of ways, which are only partly captured in revenues (or cost changes).

Qualitative MOEs may include other benefits or impacts associated with the use of APTS. These relate to political and institutional coordination, human factors, and IVHS (ITS) system architecture and standards. Potential qualitative impacts are presented below.

- The use of an integrated farecard which supports a seamless transit system is desirable of riders moving from one jurisdiction into another.

- The improved quality of transit service that is possible from the increased capabilities of APTS can lead to increased ridership and passenger revenue. There are also secondary benefits, such as enhancing the image of the agency through its use of advanced technology. For example, Advanced Vehicle Monitoring and Communication (AVM/C) not only provides a method to monitor bus operation but also to perform a “town watch” service to communities served by the transit system.6 Clearly, more surveillance of criminal activities is beneficial to passengers and communities where service is provided.

- If APTS enables a transit system to operate more efficiently, passengers are less likely to complain about service, thus, providing improvements in the work environment.

- With the use of AVL, the exact location of an emergency may be found for the dispatching of assistance. It is difficult, if not impossible, to assign cost savings to the reduction in emergency response times provided by AVL.7

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VII. Methodologies

The following section describes current methodologies used for APTS and IVHS (ITS) evaluation. The pros and cons of each approach, as researched in the literature on APTS, are also presented. The methods that are discussed in this section represent those that have been used to evaluate advanced traveler information systems and advanced vehicle control systems. Creative applications of these approaches are also being used to evaluate APTS projects.

Several APTS operational tests are already underway and at various stages of completion. Research on these projects, and conversations with the project managers, have shown that several projects did not include an evaluation element using MOEs, but were used as test sites for the technology. These operational tests were conducted to monitor the functionality of the system. Some of the test are included Appendix A with the results, if any, from the test.

Research on other IVHS (ITS) applications, such as Advanced Traveler Information Systems (ATIS), Automatic Vehicle Identification (AVI), and Advance Traffic Management Systems (ATMS), revealed operational tests that included evaluation plans. These include Inform, HELP/Crescent, Pathfinder, TravTek, Smart Corridor, Advantage I-75, ADVANCE, DIRECT, Guidestar, and FAST-TRAC. The methodologies that are being employed in the evaluation of these tests, which have been applied to APTS, are presented below. A description of each method is also provided with a review of the strengths and weaknesses each evaluation methodology.

- Technical Evaluation
- Empirical Evaluation
- Model-Based Evaluation
- Subjective Evaluation

Technical Evaluation

This methodology assesses system performance and attempts to answer the questions: Was the system built properly? Is it functioning to specifications? This is a critical element in an evaluation procedure because it not only provides information on the system's functionality, but also highlights user responses to the system (e.g., survey of passengers using the system). An example of this methodology in an operational test is provided by the HELP/Crescent project. The primary purpose of this test is to determine if AVI can be used in a highway environment to collect data and to check the credentials of passing trucks at weigh stations.
**Strengths**

- In addition to providing an assessment of the system's functionality, technical evaluations describe how passengers are interacting with and responding to the system.\(^8\)

- Technical evaluation is typically employed as a control or monitoring feature to help the system operator maintain the desired level of service. It may also help to resolve some negative user responses, such as poor reliability and breakdowns.

- If an operational test starts before the system is operating up to specifications then the empirical evaluations may be biased on the downside.\(^9\) Technical evaluation provides assurances that the system is performing well, and if information collected on certain elements in the evaluation is valid.

**Weaknesses**

- Technical evaluation can be labor intensive, and may cause significant expenses to be incurred by the evaluation team. Therefore, a technical evaluation that is automated, using current computer technology, can reduce costs that are associated with this effort and increase the reliability of this approach.

- Using passenger surveys and on-site observations to assess the functionality of APTS provides a limited sample of the system's performance and passenger responses to the system. This may result in an evaluation that is biased and not representative of the system's performance at higher levels of market penetration.

- In many cases, the vendor is performing the evaluation of its technology or product, thus, not assuring an unbiased assessment.

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\(^9\) Ibid.
Empirical Evaluation

Empirical evaluation uses data collected on selected MOEs during the operational test. The IVHS (ITS) literature reveals six areas of empirical evaluation that are being used to assess APTS projects. These areas are:

1. user operation and interface design
2. user perception and preferences
3. user behavior and individual impacts
4. direct traffic impacts
5. higher order impacts
6. institutional factors

User Operation and Interface Design

This approach is generally called human factors research. The method addresses questions which relate to the "user-friendliness" of the system and ways to make improvements in the design of the system. Typical MOEs in this approach include travel time and speed variance, response time, and usability. An example of the use of this method is provided by the Travel Technology (TravTek) operational test. Travtek provides traffic congestion information and route guidance information to drivers of vehicles that are equipped with TravTek in-vehicle systems.\textsuperscript{10} The operational test is designed to collect data on how the in-vehicle navigation display affects driving performance (i.e., safety and navigation behavior) and how easy the system is to use and to learn.

User Perception and Preferences

The evaluation of user perception and preferences provides an assessment of the potential market for the system, whether the public will accept it, and support it with public resources (tax dollars). The standard method of assessing transit riders interest in using potential APTS products involves stated preference surveys. The responses are analyzed which provide an indication of respondents' attitude toward the product, and ultimate use of the system.

User Behavior and Individual Impacts

The user behavior and individual impacts method is designed to measure the improvements in a transit system's performance and operation that result from APTS. The basic design of this method is generally a comparison of data collected on selected MOEs, such as service delivery,

worker productivity, user acceptance, equipment performance and reliability, safety and security, and cost and revenue effectiveness. Baseline data are collected before the test and are then compared with data collected during the test.

Two main types of comparison are used: before versus after and experimental versus control. An example of this approach is presented in Pathfinder, an operational test of an in-vehicle urban freeway navigation and information system. It was conducted with the development of a Smart Corridor in the Los Angeles area. The primary feature of this test is that vehicles from the experimental group (equipped with navigation and information systems) are matched with vehicles from the control group. Vehicle travel times are then compared between selected origins and destinations.

**Direct Traffic Impacts**

The direct traffic impact approach assesses the ability of APTS to contribute any improvements in traffic measures. MOEs used in this approach include number of single occupant vehicles during peak hours, traffic smoothing on highways, accidents, transit ridership, and commuters in ridesharing programs. An example of this approach is represented by the Seattle Smart Traveler project. This project examines ways in which mobile communications, such as cellular phones, can make ridesharing (carpooling and vanpooling) more attractive to "drive-alone" commuters.

**Higher Order Impacts**

Higher order impacts are those impacts that result from APTS but are largely unintended and uncontrolled by the system. The MOEs (impacts) used in this approach are air quality, noise, and fuel consumption. These are well-known impacts of any transportation plan and are given consideration in most evaluations of operational tests.

**Institutional Factors**

This approach specifically looks at the institutional environment. This includes assessing the impact that APTS will have on the transit agency personnel, community goals, system architecture, product and tort liability issues, and jurisdictional relationships.

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Strengths

• Empirical evaluation helps to establish databases that are needed for calibration and validation of traffic models that are also used to evaluate other IVHS (ITS) operational test, as well as the potential risk associated with investing in the system.

• This approach is also useful in collecting data as a yardstick to measure additional improvements to the system, if more are anticipated.

• Data collected from empirical evaluation of an operational test provides information on how the system performed and whether there were any benefits.

• When applied properly, this approach provides the greatest assurance that any improvements in service operation are due to an operational test.

Weaknesses

• The empirical evaluation approach involves tedious collection of specified data, which can be costly.

• In cases where empirical data is collected for a before versus after evaluation, the results may fail to show how the system affected any significant change in MOEs. Similarly, the data collected in experimental versus control evaluation may not provide an indication of the amount of change attributable to the system.

• The accuracy of test results and thus the decision to make permanent investments in the system being tested is based on the validity of the baseline data and the data collection process. This may require additional efforts to ensure that quality information is being collected.

• Since this method requires data that will be collected during the time span of the project, it is possible that substitute data will be needed to account for changes in the external and internal environment. This aspect in the empirical evaluation may cause a misrepresentation of the results of an operational test.

• To have a significant level of confidence in the results of an operational test, the external conditions affecting the test must be similar to the external conditions that existed before the test. This is difficult, if possible, to assure.
Model-Based Evaluation

Model-based evaluations simulate the potential benefits and impacts of APTS. Models are used primarily in prospective evaluations to assess the future benefits of an APTS, considering trends in trip demand and market penetration of the system.

Using the model-based approach to evaluate an APTS application provides data that represents the limits of improvement under a particular set of assumptions. For example, in Cincinnati, estimates based upon operational tests of 30 buses showed that an AVM/C system, if implemented system wide, could reduce platform hours by 8.2 percent, contributing to a 2 percent reduction in the agency budget.12

Strengths

- As presented in the narrative above, models provide flexibility in evaluating various APTS strategies without the added cost and risk associated with full deployment of a system.

Weaknesses

- Using models to evaluate the effects of an APTS system requires travel demand (i.e., origin-destination) data that implies a massive data collection effort.

- Simulation of APTS applications needs to include mechanisms for representing various types of systems and their capabilities. For example, a geographic update mechanism where a vehicle provided information to passengers on the next scheduled stop when passed a specific point in the simulated network would represent an AVL system.

- Owners of the technology (i.e., software) may be reluctant to release their property to a model-based evaluation effort. For example, if the model uses parameters that do not represent the real world accurately enough then the results will not reflect the true potential of the system.

- Public transportation is not a closed loop control system. Decisions by users of the system can neither be simulated, nor can the decisions by non-users of the system be expected to remain in static equilibrium.

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12Morlok et al., p. 16.
Models cannot account for changes in travel demands resulting from other impacts on public transportation (i.e., land-use policies).

Subjective Evaluation

At some point in an operational test, the information from the technical, empirical, and model-based evaluations should be analyzed by transit operators. A subjective evaluation of the project should be made concerning the benefits of the APTS application compared to the cost of the system.

CBA is commonly used to aid decisionmakers in assessing the feasibility of proposed projects. CBA involves the quantification of the time stream of costs and benefits as determined through technical, empirical, and model-based approaches.13

The major steps in performing a cost-benefit analysis are provided below, along with a brief description of each.14

1. Defining the problem - Although this may seem relatively simple, it is perhaps the most important step in performing the analysis. The decisionmaker and the analyst must have a clear understanding of the task at hand.

2. Designing the analysis - The cost-benefit analysis should be designed early in the process, prior to data collection and cost and benefit estimation. The formal design should include the determination of the measure(s) to be used (e.g., net present value, benefit-cost ratio), preliminary identification of assessment costs and benefits, establishing the scope of the quantitative and qualitative components of the analysis, selection of a sensitivity analysis, and the determination of data to be collected.

3. Collecting the data - Once the problem is clearly defined and the analysis has been effectively designed, the process for collecting the data must be initiated.

4. Performing the analysis - Once the data are collected, the analysis can be performed. The quantitative analysis compares the time stream of benefits and costs for each project scenario to the baseline scenario, or "do nothing" alternative. In addition, a

13 Underwood and Gehring, p. C-38.

qualitative or social impact analysis should be conducted to include benefits and costs that are not be quantifiable within the scope of the analysis.

(5) Presenting the results - In order for a cost-benefit analysis to be useful to decisionmakers, the results must be presented in a clear and simple manner. Consideration should be given as to how to present the results in order to enhance understanding of the analysis.

An example of this traditional approach is provided by the Radio/AVL Cost Benefit Study for the Regional Transit District (RTD) in Denver, Colorado. The study compared the cost and benefits of updating RTD's current radio system with the alternative of replacing it with a radio/AVL system. Quantitative MOEs for this study included benefits that directly influence RTD's operating statement through a reduction in manpower requirements, a more efficient use of capital equipment, or an increase in ridership. Qualitative MOEs included:

- a reduction in passenger complaints as a result of buses running more efficiently;
- allowing the radio dispatcher to respond to priority calls and to direct assistance to those areas of most urgent need (i.e., responding to silent alarm and vehicle breakdowns);
- relieving congestion on roads and improving air quality; and
- "neighborhood watch" program.

This study demonstrated that the benefits of the radio/AVL system outweighed the incremental cost of replacing the current system.

A type of cost-benefit analysis was developed by Morlok, Bruun, and Blackmon that involves the use of data obtained by transit systems for Section 15 reports. An example of this approach is given in a report entitled "Advanced Vehicle Monitoring and Communication Systems for Bus Transit: Benefits and Economic Feasibility."\(^{15}\)

The focus of the Morlok research was to advance the state-of-the-art in the evaluation of Advanced Vehicle Monitoring and Communication systems (AVM/C). AVM/C refers to an AVL system that also includes advanced communication capabilities. Two major conclusions resulted from the Morlok study:

\(^{15}\)Morlok et al., p. 38.
(1) AVM/C systems have great potential for improving the productivity of bus transit by either decreasing operating costs, increasing revenues, or some combination of both, depending upon the objectives of the transit system.

(2) AVM/C systems have the potential to recoup their entire cost from operating and capital cost savings.

These conclusions were based on secondary data sources, such as studies conducted in Cincinnati and Toronto. In Cincinnati, an operational test of AVM/C was conducted with 30 buses. Results of the study suggest that, if implemented system-wide, AVM/C could reduce peak hour buses by 2 percent. In addition, the weekday bus miles declined by 7.2 percent, while platform hours were reduced by 8.2 percent. This was translated to a 2 percent reduction in the agency budget. Another study that was conducted in Toronto concluded that routes equipped with AVM/C required 4.3 percent to 9.2 percent fewer buses than other routes. Several other examples were also cited in the Morlok study. Based on these conclusions, a breakeven analysis was developed to assist in determining the productivity improvements necessary to breakeven on an AVM/C investment.

**Strengths**

- The information assembled in a cost-benefit analysis can provide decisionmakers with a summary net present value of a project.

- In cases where benefits are difficult to quantify, or if alternative projects are considered, a uniform level of benefits can be assigned and then projects can be evaluated based on cost.

- In reference to the transit cost model approach, data available from Section 15 reports enable estimates of the potential benefits of APTS to be conducted at a lower cost than other approaches.

**Weaknesses**

- Inherent to this approach is the difficulty in quantifying certain benefits and costs, such as the value of a life and the need to conduct a qualitative or social impact analysis.

- Cost-benefit analysis provides decisionmakers with one dimension of the investment, or investments being considered. This approach omits certain qualitative benefits in its analysis.
• The benefits in a cost-benefit analysis are represented in dollar values rather than quantitative utilities such as, time savings in seconds or fuel consumption in gallons.

• Results from this analysis are only as good as the data employed. It is especially true for the CBA approach that is advocated by Morlok et al. If the Section 15 data used in this approach are not accurate than the information provided on the cost-effectiveness of APTS will not be credible.
VIII. Emerging Approach in Evaluation of APTS\textsuperscript{14}

The Volpe National Transportation Systems Center (VNTSC) is developing a set of APTS Evaluation Guidelines that provide a common framework and methodology for evaluating individual operational tests. This project is being sponsored by the APTS program of the FTA. The guidelines are not intended to be all inclusive, since each operational site is unique; each site requires a tailor-made evaluation plan or process based on the model Evaluation Guidelines.

The evaluation process consists of four major phases:

(1) Evaluation Frame of Reference

The evaluation reference establishes the operational test background and description. It includes local objectives, issues, site characteristics, and potential external influences.

(2) Evaluation Planning

The evaluation planning phase of the process transforms the evaluation frame of reference into a detailed, structured plan for conducting the evaluation. This plan contains the MOEs, data collection sources and requirements, and evaluation methodology. MOEs have been organized into the following categories: financial impacts, functional characteristics, user acceptance, transit system efficiency and effectiveness, and other impacts.

(3) Evaluation Implementation

The evaluation implementation phase is the period during which the evaluation plan is executed.

(4) Evaluation Spin-Offs

Final evaluation reports are anticipated so that other interested parties may share in the findings.

In addition to this effort, and beyond the operational tests of APTS that have been presented, several studies have been conducted on the benefits and costs of IVHS (ITS) technologies and strategies. These studies are analyzed in a document entitled \textit{Analysis of IVHS Benefits/Costs Studies} (Volpe National Transportation Systems Center, 1993).

\textsuperscript{14}Information in this section was obtained from a draft copy of "Evaluation guidelines for the Advanced Public Transportation Systems Operational Tests." A final draft is being completed by the Volpe National Transportation Systems Center.
IX. Lessons Learned

This research has provided an opportunity to identify the approaches used to evaluate operational tests of APTS, and other activities involving this technology. The evaluation provides information to transit decisionmakers so that investment strategies can be formulated. Lessons that were learned because of this research effort are presented below.

- The investment of resources (i.e., time, labor, fiscal, etc.) in this technology varies substantially from project to project. This variance in investment depends on several factors. These may include: technology, performance features of the equipment, complexity and size of transit system, and vendors. Specifications on each of these factors and how they will be affected by the system being tested should be included in the evaluation of an operational test.

- The methodologies that have been reviewed in this research include technical, empirical model-based, and subjective. Each provides transit decisionmakers with an evaluation of APTS. The literature suggests that an improvement to the evaluation process may result when a combination of approaches is used (i.e., empirical evaluation with subjective evaluation).

- A standard automated data collection and reporting technique should be developed. The primary benefit of this effort is that it would produce data that is consistent and reliable, especially for operational tests involving empirical data. It also allows comparisons between transit systems for similar operational tests.

- To increase the body of knowledge on APTS, agencies that are involved in operational tests should be required to make timely documentation of their results. A system should also be developed to disseminate this information.

- More research should be conducted on ways to identify public and private benefits equitably. For example, the driver of a single occupant vehicle may realize the benefits of a Passenger Information Display System, then decide to use transit. By eliminating this driver from the local road network, it also reduces congestion by a single vehicle. This translates into a private benefit to drivers that continue to drive on the local road network with less congestion.

- The IVHS (ITS) products that are being developed need to be accepted and understood by the public. Potential users of the system cannot be expected to realize the full benefits of the system until they are well adapted. Research on integrating this time sequence into the evaluation effort should be pursued.
• Existing models lack the ability to represent APTS functions, such as passenger responses to an information display. An effort should be made to update existing models to reflect not only the functionality of APTS but the impact on the users of the system.

• As additional APTS products are developed and potential users become familiar with the benefits of these systems, and assuming they reach full market penetration (i.e., breakeven point), it becomes difficult to evaluate the impact of these systems on the public. For example, drivers could become more attracted to transit after learning of the benefits of an integrated fare payment system. As ridership increases, congestion on the local road network decreases, which may influence those drivers that switched to transit to drive again.

• Various scenarios should be used to assess the impacts of APTS on institutional factors such as mode shifts and travel demand. Efforts should be made to identify features that either support or suppress a successful implementation of an operational test. For example, FTA gives preference to operational test which include cost sharing between a local agency, private vendor, and independent evaluator.

• Guidelines for performing evaluations on operational test are being developed by The Volpe National Transportation. These guidelines provide a common framework and methodology for evaluating individual operational tests. In addition, studies have been completed on the benefits and costs of IVHS (ITS) technologies and strategies. These studies are analyzed in a document entitled Analysis of IVHS Benefits/Costs Studies (Volpe National Transportation Systems Center, 1993).

The methodologies presented in this report are based on the scientific approach (i.e., data analysis, surveys, models, and field observations). Most APTS operational tests include an evaluation using one or a combination of the approaches documented in this research. Except subjective evaluation or CBA, these methodologies are useful in evaluating APTS capabilities, their impacts on transit operations, and the potential for these systems to influence travel behavior. They are not, however, appropriate for deciding if an investment in APTS is cost effective.

Perhaps the most significant lesson learned from this research effort is the need for further development in the area of subjective evaluation or CBA. The review of APTS applications in the U.S. revealed very few efforts to evaluate these projects through CBA. For some projects, a CBA is not included. In most tests, this analysis is planned as the final step in the project evaluation, after a field test has been completed and potential benefits have been reported.
Several operational tests that are presented in Appendix A are in field evaluation and have not reached the CBA phase.

Guidelines on performing evaluation of APTS are already being developed by the VNTSC. Notwithstanding these guidelines, specific guidelines are needed on evaluation of APTS projects using CBA.

In a subsequent report to this research, guidelines will be established and recommended for evaluating APTS investments. This includes providing methodologies for determining if an APTS investment is feasible and monitoring APTS projects currently being tested. This effort will also assess the cost effectiveness of APTS investments as compared to traditional public transportation investments.
Appendix A
Scope and Status of APTS Operational Test Projects

The following section identifies and summarizes past, current, and planned APTS operational tests in the U.S. Listed for each operational test is the project name and/or sponsoring agency, project site, the type of APTS application, the project description, the purpose for implementing the project, the method and measures of evaluation used, and the results (status) of the project versus its stated objectives.
<table>
<thead>
<tr>
<th><strong>Project Name:</strong></th>
<th>Dade County Passenger Information System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sponsoring Agency/Site:</strong></td>
<td>Metro Dade County Transit Agency / Miami-Dade County</td>
</tr>
<tr>
<td><strong>APTS Application:</strong></td>
<td>Pre-trip Passenger Information Systems</td>
</tr>
<tr>
<td><strong>Project Description:</strong></td>
<td>Voice-actuated system accessed by phone (rotary or touch-tone) that digitizes the voice to recognize the request. The request is then matched, and route information is provided back to the user. This system frees up operators to handle more complex trip planning requests. The system has been operating approximately two years and provides information for bus and rail service.</td>
</tr>
<tr>
<td><strong>Project Purpose:</strong></td>
<td>This system is being tested to improve the agency's ability to respond to passengers requesting information.</td>
</tr>
<tr>
<td><strong>Evaluation Method:</strong></td>
<td>Measurements are taken to determine the number of additional request serviced as a result of implementing the system. Market research activities are also underway to get public perceptions to the new service.</td>
</tr>
<tr>
<td><strong>Results (Status):</strong></td>
<td>Automated system reduced the amount of time per call being spent which allowed for greater capacity of service. Future plans are to add user-friendly terminals and key transfer points and rail stations. AVL system is scheduled to be operational in two years 800-MHz radio and GPS and will be tied into the existing information system to provide real-time data.</td>
</tr>
<tr>
<td><strong>Contact:</strong></td>
<td>Louis Revas - (305) 375-3203</td>
</tr>
</tbody>
</table>
Project Name: "Teletrip", The Long Island Railroad Project
Sponsoring Agency/Site: Long Island Railroad (LIRR) / New York City
APTS Application: Pre-trip Passenger Information
Project Description: Computerized system, designed by Next Generation, Inc., to handle incoming calls and provide schedule and fare information by means of a computer-generated voice. System analyzes calls and supplies requested information. System also has ability to play a pre-recorded message on train schedules or emergency operational delays.
Project Purpose: This system has been implemented to increase the number of information seekers that are able to be serviced and to decrease the required workforce necessary to handle those calls.
Evaluation Method: Much of the evaluation work was done initially before the purchase of the system
Results (Status): System was installed in 1989. Since that time the overall system capacity has been increased twice from 16 lines to 72, and again to 100 lines. A 33 percent increase, from 2 million in 1991 to 3 million in 1992, in the number of calls handled has also been realized by the system. 55 percent of all calls coming into the system are handled by "Teletrip." LIRR officials estimated in 1990 that every call results in $2.34 of revenue.
Contact: Brian Dolan, Public Relations - (718) 990-7301
Project Name: Houston Smart Commuter

Sponsoring Agency/Site: FTA, FHWA, Texas Department of Highways and Public Transportation, and the Texas Transportation Institute, Metro Transit Authority of Harris County / Houston Metro

APTS Application: Real-time Passenger Information and In-terminal Information.

Project Description: The project assesses the market potential for ride-sharing activities by supplying traffic information to the public. Cost-effective alternatives for collecting and disseminating traffic information are identified and evaluate. Project administrative requirements and projected costs are also identified. Data integration with existing "Digiplan" project, which provides in-terminal information using GIS databases and touch-screen technology, is planned.

Project Purpose: This project seeks to develop and evaluate a real-time traffic and transit information system for the Harris County area.

Evaluation Method: Four categories of evaluation criteria are used to judge the progress of the demonstration: desired system characteristics, compatibility with other METRO and state highway and public transportation projects, costs, potential for private sector involvement.

Results (Status): Concept development stage has been completed. Interagency agreements between team members are currently being negotiated.

Contacts: Denis Symes - (202) 366-0232
Darryl Puckett - (713) 739-6093
Project Name: Detroit Transportation Center Transit Information

Sponsoring Agency/Site: FTA, FHWA, Detroit Department of Transportation / Detroit

APTS Application: Real-time Passenger Information

Project Description: Use of buried inductive loops to collect traffic information for 32 miles of freeway. Traffic condition information is provided to highway management centers for dissemination to public transit agencies. Information is graphically displayed on monitors by color coding freeway segments by speed.

Project Purpose: To demonstrate the ability to provide this information inexpensively and assess its value to transit organizations.

Evaluation Method: To be determined. Volpe report on evaluation criteria due to be released soon. It is believed that criteria from that report will be used to measure the effectiveness of the project.


Contacts: Sean Ricketson - (202) 366-6678
Janet D'Ignazio - (517) 373-2834
Project Name: California Smart Traveler

Sponsoring Agency/Site: FTA, CALTRANS / Suburban California

APTS Application: Pre-trip Passenger Information.

Project Description: Information system will permit residential and business users to access timely travel information using remote access computers over telephone lines. Users will be able to identify and reserve travel options through the use of the system. Both public and private sectors will test an advanced traveler information system as part of the project through the use of voice mail and kiosk interfaces.

Project Purpose: This project will support efforts to design, operationally test, and evaluate the California Advanced Public Transportation Systems (CAPTS) program. IVHS (ITS) technologies will be applied to transit, paratransit, and ridesharing operations.

Evaluation Method: Proposals for an evaluation plan are being reviewed. Chosen contractor will reference Volpe evaluation plan (when completed) and develop specific plan for the project.

Results (Status): Three information systems have been hooked into the pre-trip information system: CALTRANS, ride-share contractor, and Metropolitan Transit Authority databases.

Contacts: Ron Boeneau - (202) 366-0195
Robert Ratcliff - (916) 323-2644
Project Name: Seattle Smart Traveler

Sponsoring Agency/Site: FTA, Bellevue Transportation management Association, University of Washington, City of Bellevue, Washington DOT / Seattle-Bellevue, WA

APTS Application: Real-time Rideshare Matching

Project Description: Phase I is an innovative technology approach combining cellular communications, voice mail, and computerized real-time information processing to make ridesharing more attractive. Phase II will operationally test prototype computer-based interactive commuter information centers in downtown Bellevue. Dynamic ride-sharing services available via phone and pagers.

Project Purpose: This project strives to expand the area's rideshare matching system and to supply information to rideshare vehicles which provides an advantage over single occupancy vehicles. It is hoped that a new kind of information infrastructure can be forged through the application of these new technologies.

Evaluation Method: The focus of the evaluation is on the increase participation in ride-sharing activities. Tremendous effort is being made to provide and promote ride-sharing services. Activities will be monitored in two areas. First, from the machine side how many connections (rideshares) will be made through the use of the system (the system will keep track). Second, an assessment will be made as to the human response to the system and the overall impact on travel behavior.

Results (Status): The pieces are in place to begin a 6-month operational test for providing dynamic ride-sharing services. Services should be offered in 1993.

Contacts: Ron Boeneau - (202) 366-0195
Mark Haselkorn - (206) 543-2577
Project Name: California Smart Public Transportation

Sponsoring Agency/Site: Metropolitan Transportation Commission / Oakland, CA
Metropolitan Transportation Commission / Los Angeles, CA

APTS Application: Integrated Fare Media

Project Description: Two similar projects under the California Advanced Public Transportation Systems (CAPTS) umbrella using magnetic-strip cards for combining the fares of bus and rail services. Study areas are in the cities of Oakland and Los Angeles and include transit agencies from both areas. Volunteers use magnetic-strip cards to pay fares. New vending equipment is to be installed in major downtown stations and suburban areas.

Project Purpose: These projects test the equipment and electronics associated with smart card technology. The goal is to examine the ability of smart card technology to reduce overall traveler commute times by removing the need for separate fare media.

Evaluation Method: Evaluation plan will be develop in coordination with the Volpe evaluation plan (when completed). Specific measures for integrated fare media will be incorporated.

Results (Status): None specified

Contact: Joel Markowitz - (510) 464-7760
Project Name: Norfolk Mobility Manager

Sponsoring Agency/Site: FTA, Tidewater Transportation District Commission / Norfolk, VA

APTS Application: Mobility Manager

Project Description: The provision of subsidies to low-income transit riders to encourage private operations to provide better transportation services. The Tidewater Transportation District Commission will distribute 'mobility vouchers' to employees who pay face value for the vouchers or qualify for the benefit. Voucher distribution will also be coordinated with social service agencies, especially the medical area.

Project Purpose: This project is designed to evaluate how transit and paratransit subsidies can improve transportation services to low-income riders by focusing on the employer difficulties in getting low-income wage earners to overcome transportation barriers to employment.

Evaluation Method: To be determined

Results (Status): Project to date has been a success by evidence of increasing sales.

Contact: Helen Tann - (202) 366-0207
Project Name: Rogue County Mobility Manager

Sponsoring Agency/Site: FTA, Rogue Valley Council of Governments, Call-a-Ride, Upper Rogue Community Centers, Rogue Valley Transportation District / Medford, OR

APTS Application: Mobility Manager, Provider Information System, Electronic Fare Media, Dispatch Services.

Project Description: Use of magnetic-strip cards to integrate transportation users, providers, and funding sources. Advanced electronic technology is used to record financial transactions. Radio and cellular data transmission are used.

Project Purpose: This project is designed to provide transportation services to the elderly and disabled who are unable to use fixed-route transit and to demonstrate the mobility manager concept for frequent transit riders in urban and rural environments. It is hoped that future stages lead to widespread public participation.

Evaluation Method: To be determined based on the Volpe Plan.

Results (Status): A project steering committee consisting of operators and consumers has been organized to assist in the development and management of the project. Easy Street has been contracted to develop and install all hardware and software systems. Three month development schedule due to begin in November, and operations should begin by February 1994.

Contacts: Ron Boeneau - (202) 366-0195
Gary Shaff - (503) 664-6674
Project Name: Bus Card Plus Program

Sponsoring Agency/Site: City of Phoenix, Phoenix Transit / Phoenix, AZ

APTS Application: Smart Cards

Project Description: Use of magnetically-coded credit card to pay bus fares. The card reader is placed directly on top of the farebox and accepts magnetically-encoded information from a standard credit card pass. System has been operational since April 1991, incorporates the entire bus fleet (370 buses), and has five fare categories: monthly passes, daily passes, disabled, senior citizens, and youth. Local businesses are signed up in the program to supply cards to employees for use. Fares are collected from the businesses and subtracted from employee paychecks.

Project Purpose: This project works to facilitate the payment of bus fares through electronic media. The program initially started with transit employees and then expanded to a larger employee pool involving local companies. The ultimate goal is to be a cashless bus system.

Evaluation Method: Evaluations are strictly done on increased transit ridership. Other data on rider type, on-time bus performance, and transaction accuracy and validity are collected but important to the success of the project.

Results (Status): Fare card program has been operational for a year and a half. The speed of boarding has increased. Ridership has increased. Other benefits realized include the type of information that can be collected to improve overall service, including rider profiles and entry/exit points. In the future bank cards or credit cards will be accepted.

Contact: Jimmy Sue Olson - (602) 262-7584
Project Name: Washington Metropolitan Area Transit Authority

Sponsoring Agency/Site: Washington D.C.

APTS Application: Smart Cards.

Project Description: Use of a credit card to pay bus and rail fares.

Project Purpose: 1) To test advance fare technology; 2) To experiment with a sturdier fare card than is currently being used by the system; 3) To eliminate the need for bus passengers to have change to pay fares.

Evaluation Method: No evaluation methodology given.

Results (Status): None specified.

Contacts: Ramon Abromovich - (202) 962-5274
Irv Chambers - (202) 366-0238
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<thead>
<tr>
<th>Project Name:</th>
<th>Travlink / Twin Cities Smart Traveler</th>
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<tbody>
<tr>
<td>Sponsoring Agency/Site:</td>
<td>FTA, Minnesota Department of Transportation, Metropolitan Transit Commission, Regional Transit Board, University of Minnesota / Minneapolis-St. Paul, MN</td>
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<tr>
<td>APTS Application:</td>
<td>Smart Cards, Real-time Traveler Information, Automatic Vehicle Location.</td>
</tr>
<tr>
<td>Project Description:</td>
<td>Two separate projects utilizing IVHS (ITS) technologies for the enhancement of public transportation systems. &quot;Travlink&quot; plans are being designed to use AVL for bus tracking and to provide real-time travel information to transit users and ridesharers at home, work, and transit terminals. &quot;Smart Traveler&quot; utilizes smart card technologies for advanced fare payment and electronic billing to improve transit and paratransit service. Possible link-ups between the two projects will be investigated.</td>
</tr>
<tr>
<td>Project Purpose:</td>
<td>The &quot;Travlink&quot; project will examine the usefulness and effectiveness of providing travel information to transit users. &quot;Smart Traveler&quot; will examine the best fare payment application, evaluate the smart card potential for electronic billing, study the potential of monitoring contractor performance through smart card systems, and determine the smart card potential on standard transit routes.</td>
</tr>
<tr>
<td>Evaluation Method:</td>
<td>Consultant, Cambridge Systematics, hired to do evaluation of the operational test. Evaluation criteria will be developed with special attention being given to the evaluation plan developed by the VNTSC.</td>
</tr>
<tr>
<td>Results (Status):</td>
<td>Applied Systems Institute, Inc. has been contracted to conduct the study to assess smart-card benefits for individual transit operators. Plans are being developed toward the implementation of a pilot project on 12 buses scheduled to begin in March 1994.</td>
</tr>
</tbody>
</table>
| Contacts:                   | Sean Ricketson - (202) 366-6678  
<pre><code>                        | Howard Blin - (612) 292-8789 |
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<thead>
<tr>
<th><strong>Project Name:</strong></th>
<th>Dallas Smart Bus</th>
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<tbody>
<tr>
<td><strong>Sponsoring Agency/Site:</strong></td>
<td>FTA, Dallas Area Rapid Transit / Dallas, TX</td>
</tr>
<tr>
<td><strong>APTS Application:</strong></td>
<td>Automatic Vehicle Location</td>
</tr>
<tr>
<td><strong>Project Description:</strong></td>
<td>Use of an Integrated Radio System (IRS) and GPS technology to track a fleet of 1500 buses, transit supervisor vehicles, mobility-impaired vehicles. &quot;Report by exception&quot; strategy being used. Service area is very large (900 square miles) and position accuracy of buses is desired.</td>
</tr>
<tr>
<td><strong>Project Purpose:</strong></td>
<td>This project wishes to develop an AVL system to integrate police vehicles, to serve as a management tool, and to determine the cost-effectiveness of the GPS/IRS technology combination to control bus schedules.</td>
</tr>
<tr>
<td><strong>Evaluation Method:</strong></td>
<td>No specific evaluation criteria being used on the benefits to the users and community, however, a 43 percent increase in efficiency for handi-ride services (mobility-impaired) was realized. Transit agency is administering their own performance analysis of the equipment.</td>
</tr>
<tr>
<td><strong>Results (Status):</strong></td>
<td>Operational system started in May 1992. The IRS/GPS equipment is currently installed and operating in 1160 buses. Central software for route adherence not yet complete so project is only 70 percent complete.</td>
</tr>
</tbody>
</table>
| **Contacts:** | Denis Symes - (202) 366-0232  
Paul Ledwitz - (214) 749-2837 |
<table>
<thead>
<tr>
<th><strong>Project Name:</strong></th>
<th>Ann Arbor Smart Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sponsoring Agency/Site:</strong></td>
<td>FTA, Ann Arbor Transportation Authority (AATA), City of Ann Arbor, University of Michigan / Ann Arbor, MI</td>
</tr>
<tr>
<td><strong>Project Description:</strong></td>
<td>Several different applications of IVHS (ITS) technologies utilized for improving the bus operation in Ann Arbor. Three components are stressed for improvement: operations control, on-board systems and customer information systems. Use of GPS for vehicle location. On-board systems monitor performance and collect data for bus identification, route, speed, incident reporting and engine status. Customer information systems and services include in-bus displays and &quot;Talking Bus&quot; features to signal stops and smart cards to provide dual farecard/parking pass for encouraging car drivers to ride transit.</td>
</tr>
<tr>
<td><strong>Project Purpose:</strong></td>
<td>This project will conduct an operational test of the &quot;Smart Bus&quot; concept and integrate several IVHS (ITS) technologies for the purpose of enhancing transit services and improving overall mobility. The project will help the AATA meet a broader set of goals defining their intent to provide the highest level of transit service to the community.</td>
</tr>
<tr>
<td><strong>Evaluation Method:</strong></td>
<td>No evaluation methodology given.</td>
</tr>
<tr>
<td><strong>Results (Status):</strong></td>
<td>AATA has issued a RFP for system procurement defining functional specification. Proposals are due in October 1993, and a contractor choice is expected in November 1993. Initial plans will focus on developing the smart card fare and parking system, then equipping a portion of the bus fleet with the previously mentioned systems.</td>
</tr>
</tbody>
</table>
| **Contacts:** | Sean Ricketson - (202) 366-6678  
Michael Bolton - (313) 973-6500 |
<table>
<thead>
<tr>
<th><strong>Project Name:</strong></th>
<th>Toronto Transit AVL System</th>
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<tbody>
<tr>
<td><strong>Sponsoring Agency/Site:</strong></td>
<td>Toronto Transit Commission / Toronto, Ontario, Canada</td>
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<tr>
<td><strong>APTS Application:</strong></td>
<td>Automatic Vehicle Location, Advanced Vehicle Monitoring and Communications System</td>
</tr>
<tr>
<td><strong>Project Description:</strong></td>
<td>Use of odometer/signpost based system, voice/data radio, microprocessor, keyboard, and display within transit buses for current location designation and deviation control. A large operation involving 2300 buses and streetcars along with several transit (subway) vehicles. Vehicle locations are polled once every six seconds and transmitted via radio channel to control center. Automatic passenger counters are also used but are coordinated with the AVL for real-time data.</td>
</tr>
<tr>
<td><strong>Project Purpose:</strong></td>
<td>The project is designed to facilitate planning and scheduling for improving the operating efficiency of bus service in Toronto and to provide vehicle location information to interested parties.</td>
</tr>
<tr>
<td><strong>Evaluation Method:</strong></td>
<td>Evaluations will focus on two study areas, one downtown, on suburban, to test the validity and accuracy of the AVL system.</td>
</tr>
<tr>
<td><strong>Results (Status):</strong></td>
<td>None specified</td>
</tr>
<tr>
<td><strong>Contact:</strong></td>
<td>Joe O'Connell - (416) 393-4373</td>
</tr>
</tbody>
</table>
Project Name: Chicago Smart Bus

Sponsoring Agency/Site: FTA, Chicago Transit Authority, City Department of Public Works, City Department of Streets and Sanitation / Chicago


Project Description: Development of a BSMS that will utilize various IVHS (ITS) technologies for dispatching and managing bus and paratransit operations. The system will support operations and provide schedule adherence information to dispatchers. Unique features of the system include: 1) headway adherence by means of text displays which show the bus driver the headway for the preceding and succeeding buses; and 2) computer-aided service restoration (CASR) which identifies the most critical system situation and suggests alternative courses of action. Extensive on-board data collection will also be done in support of the operational evaluation to be completed.

Project Purpose: This project will document the process of implementing a BSMS and provide for more efficient and effective bus operations. The project will also analyze the human-factors element of BSMS by assessing the effects of introducing video terminals and information systems into the transit dispatching environment.

Evaluation Method: The evaluation criteria used to measure cost-effectiveness will be the plan being developed by the Volpe National Transportation Systems Center (VNTSC).

Results (Status): Vendor proposals have been reviewed for hardware and software designs. Contract negotiations are in progress. Vendor choice expected by end of 1993. Operational demonstration on 85 buses will be in place by end of 1994.

Contacts: Sean Ricketson - (202) 366-6678
Jim Blanchard - (312) 245-9170
Project Name: Baltimore Smart Bus

Sponsoring Agency/Site: FTA, Maryland Mass Transit Administration / Baltimore, MD

APTS Application: Automatic Vehicle Location.

Project Description: City buses and supervisory vehicles are equipped with LORAN-C receivers and 800 Mhz radios for location tracking. Bus location is determined and transmitted to dispatching centers where corrective actions can be taken for off-schedule buses. Next project development phase will utilize GPS technology for bus locations, make bus information available to current and would-be passengers by providing information displays in the home and workplace. Computer-aided dispatch for the bus fleet will also be tested.

Project Purpose: This project will create the ability to provide bus status information to bus dispatchers and the general public. The benefit of such information will be improved bus operating schedules, labor productivity, and greater utilization of the fleet.

Evaluation Method: To be determined

Results (Status): Phase II demonstration is operational to determine its potential with 50 buses, 4 supervisory vehicles, and 2 color consoles. Driver feedback on schedule adherence is available to control routes. Phase III is out for bid in September 1993 and will utilize GPS in place of LORAN-C for vehicle locations. Entire bus fleet will be equipped for AVL. Realized benefits include better utilization of bus fleet, better on-time performance, less on-air time for drivers, and a better overall understanding of operations.

Contacts: Denis Symes - (202) 366-0232
Ray Carroll (410) 333-3430
Project Name: Denver Smart Bus

Sponsoring Agency/Site: Denver, CO

APTS Application: Automatic Vehicle Location, Real-time Information System

Project Description: Use of GPS-based system for tracking vehicle location. Real-time traffic information will be provided to central dispatch center for controlling transit operations and travelers for decision making. Dispatch operators will monitor locations on map displays and control bus schedules. Schedule information will be provided to travelers at transit stations, park-and-ride lots, and the new Denver airport.

Project Purpose: This project will provide real-time traffic information for travelers to increase transit efficiency, ridership, and passenger safety.

Evaluation Method: System will be evaluated by FTA through Sandia National Laboratories and the Denver Regional Transportation District. Included in the evaluation will be a technical evaluation and a human factors/interface evaluation.

Results (Status): The system is installed in 833 buses and 28 supervisory vehicles. A complete operational system is expected by December 1993. A light-rail transit demonstration (eleven vehicles) is expected to be added by October 1994.

Contacts: Denis Symes - (202) 366-0232
Lou Ha - (303) 299-6265
Project Name: Passenger Waiting Time Monitoring System (PWTMS)

Sponsoring Agency/Site: Massachusetts Bay Transportation Authority (Rapid Transit Operations) / Boston, MA

APTS Application: Transit Operations Software

Project Description: Partially automated system that allows operators to compare schedule times versus actual train times. System is tied into the non-vital logic where it counts trains and compares time versus the operating schedule. Information is used to alert dispatchers and invoke exception operations procedures. Information is also provided to emergency response personnel and to passengers at stations for next train arrival.

Project Purpose: PWTMS is designed to monitor train delays, adjust flows when necessary, and announce next train arrivals to awaiting passengers.

Evaluation Method: Major measure used to track system performance is passenger waiting time (headways). However, operations themselves are altered only for exceptions.

Results (Status): PWTMS has been installed for three years. It was paid for out of the operating budgets of the rapid transit operation. Realized benefits include reduced labor and faster response by dispatchers to situations potentially causing system delays. Also a benefit in stronger relation with public due by providing train arrival information. Conceptual designs are being developed for a fully automated decision assistance system for dispatchers for rapid transit operations.
<table>
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<tr>
<th><strong>Project Name:</strong></th>
<th>Transit Network Route Decision Aid</th>
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<tbody>
<tr>
<td><strong>Sponsoring Agency/Site:</strong></td>
<td>FTA, University of Michigan Department of Industrial Operations and Engineering / Ann Arbor, MI</td>
</tr>
<tr>
<td><strong>APTS Application:</strong></td>
<td>Passenger Information Systems</td>
</tr>
<tr>
<td><strong>Project Description:</strong></td>
<td>The development of specialized techniques and algorithms for decision aid to assist telephone operator in rapidly identifying useful itineraries for passengers in mass transit systems. Upon development of such techniques an operational test could be performed for validation.</td>
</tr>
<tr>
<td><strong>Project Purpose:</strong></td>
<td>This project will develop specifications for designing, implementing, and evaluating computerized information systems.</td>
</tr>
<tr>
<td><strong>Evaluation Method:</strong></td>
<td>Not applicable</td>
</tr>
<tr>
<td><strong>Results (Status):</strong></td>
<td>Work has begun on the investigation and analysis of algorithms and specialized techniques to address problem.</td>
</tr>
</tbody>
</table>
| **Contacts:** | Sean Ricketson - (202) 366-6678  
Chip White - (313) 763-1332 |
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