ITS Enhanced Bus Rapid Transit Research and Deployment Program 2003 – 2007

-DRAFT for COMMENT-

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List of Illustrations

1.0 Introduction

This white paper provides recommendations to U.S. DOT on a number of projects to address BRT-ITS research and deployment needs over the next several years. It is evident that the BRT platform provides a unique opportunity on which to deploy existing ITS technologies. To that end, the research needs are not primarily directed towards new technologies. In fact, there are few ITS technologies that are unique to BRT. Rather, the research is focused upon utilizing, tailoring and adapting current ITS technologies to the BRT environment. These research efforts will further support the deployment and implementation of ITS technologies on both operational and planned BRT systems. In general, the BRT-ITS research needs address the following areas:

1. How existing ITS research and products can add value to BRT service;
2. Identifying integrated ITS packages appropriate for the four stages of BRT deployment;
3. Examining the inter-relationships among ITS technology, physical design, vehicle design and service operations that work together in a BRT environment; and
4. Document design and implementation similarities and differences between deploying ITS technologies for an individual BRT route versus a system-wide implementation.

The proposed recommendations are broken into seven technology areas:

- BRT System Integration
- Electronic Fare Collection for BRT Systems
- Transit Signal Priority: Adapted to the BRT Operating Environment
- BRT System Automation
- ATIS in Support of BRT
- Evaluation of BRT-ITS Impacts and Development of BRT Analysis Tools
- BRT-ITS Outreach and Training

Each technology area includes background information, current research and products (not necessarily related to BRT) and specific recommendations for additional BRT research and actions. The background provides information about the area of applicability of the technology to the BRT environment. Current research and products provide a high-level overview of available research and products that may be applicable to the BRT environment. Finally, the recommendations provide a list of specific projects to be undertaken to further the deployment of ITS technologies within BRT systems. Recommendations are separated into *New Research Projects* and *Recommended Actions*. In general, *Recommended Actions* are seen as short-term efforts that can be accomplished through current contracts, at little or no-cost, to insure ongoing projects reflect BRT-ITS needs.

It is important to note that there are a number of partnering opportunities available to leverage current projects and funding sources. Many of the BRT sites are already deploying technology. For example, Los Angeles' Metro Rapid system has an extensive transit signal priority system that is deployed and expanding every year. The time and effort put into this system and the experience gained should be leveraged to capitalize on its success, and enable other BRT sites to benefit. Other examples include the three buses that Caltrans has purchased to test various IVI technologies. Again, encouraging BRT sites to pool and leverage available funds by testing various technologies on these mobile assets would provide benefit to all players involved. Other mobile assets purchased for different testing purposes could also be used. The recommended projects presented here are meant to provide a general direction of research needs for BRT and ITS and it is expected that funding will not come from one single source, but rather multiple sources pooled together.

Table 1.1 provides an overview of all recommended new research projects and other recommended actions. Each recommendation provides its relationship (if any) to the current FTA Transit ITS Program Plan. Also, two additional categories are provided. The *Timeframe* suggests a priority for each recommendation (recommended actions are denoted by 'ACTION') and a project start year. The *Funding* includes the suggested amount and type of funding (FTA, JPO, pooled funds, etc.). In most cases the funding is 'To Be Determined.'

Table 1.1 BRT-ITS Project Recommendations

Report Section Reference	Research Projects	FTA Transit ITS Program Plan Reference Project(s)	Timeframe: Priority	Timeframe: When	Funding: Amount ($100k)	Funding: Type	Funding: Status*
BRT System Integration							
2.2.1	BRT Vehicle Systems Integration	4.13 and 4.14	High	FY03	350	JPO	FY03 RA
2.2.2	Communication Requirements for Successful BRT Systems Integration		High	FY04	400		
2.2.3	Advanced Communication System Cost		Med	FY06	400		
2.2.4	BRT Technology Procurement Guidelines		Low	FY06	250		
2.2.5	Application of Commerical Digital Wireless Data Service to Transit		Low	FY06	250		
Electronic Fare Collection for BRT Systems							
3.2.1	Implementation Guidelines for BRT EFP Systems		High	FY04	250		
3.2.2	On-Site Technical Support for EFP System Implementation		Med	FY05	500		
3.2.3	Multi-application Electronic Payment Systems	3.07	Med	FY04/05	1000	JPO	Request for FY04/05
Transit Signal Priority: Adapted to the BRT Operating Environment							
4.2.1	TSP Deployment Case Studies	4.09 and 4.10	High	FY05	300		
4.2.2	System-wide TSP and BRT: Priority Conflict Resolution for Multiple BRT Corridor(s)		High	FY05	200		
4.2.3	Cross-Cutting Assessment of TSP Impacts on BRT Operations		Med	FY06	200		
4.2.4	Field Operational Tests and Evaluation of Transit Signal Priority Algorithms		Med	FY07	600		
4.3.1	TSP Deployment Experience Survey	10.06	ACTION		-	-	Project 4.08
4.3.2	Transit Signal Priority Control Strategies and Modeling Tools	1.13	ACTION		-	-	Project 4.08
4.3.3	TSP Peer-to-Peer Technical Assistance	12.1	ACTION		-	-	Project 4.08
BRT System Automation							
5.2.1	BRT Automation Phase II: Operational Tests of Lane Assist Requirements	7.21a	High	FY04/05	1200	JPO	Request for FY04/05
5.2.2	BRT Automation Phase II: Precision Docking	7.21b	High	FY04/05	350	JPO	Request for FY04/05
5.2.3	BRT Automation Phase II: Assessment of Human Factors, Safety & Liability Risks of BRT Automation	7.21c	Med	FY05	100	JPO	Request for FY04/05
5.2.4	BRT Automation Phase II: Reliability, Availability & Maintainability of BRT Automation Technologies	7.21d	Med	FY05	100	JPO	Request for FY04/05
5.2.5	European Information Exchange	4.10	Low	FY04	75		
5.2.6	BRT Automation Phase III: Vehicle Platooning Technologies	7.22	Low	FY06	300	JPO	Request for FY04/05
ATIS in Support of BRT							
6.2.1	BRT Case Studies of ATIS Application		Low	FY05	250		
6.3.1	APTS Deployment in the United States	10.06	ACTION		-	-	Project 4.08
6.3.2	Measurement of ATIS Impacts in BRT Environment	10.25	ACTION		-	-	Project 4.08
6.3.3	Door-to-Door Multimodal Trip Planning: Demonstration (Phase 3)	2.10c	ACTION		-	-	Project 4.08
6.3.4	Personalized Transit ATIS Operational Test	2.03	ACTION		-	-	Project 4.08
6.3.5	Transit ATIS Test	2.04	ACTION		-	-	Project 4.08
Evaluation of BRT-ITS Impacts and Development of BRT Analysis Tools							
7.2.1	BRT Modeling Process		Med	FY04	400		
7.2.2	Ongoing Monitoring of ITS Utilization at BRT Sites	4.11	Med	FY04	250	JPO	
7.2.3	Performance Evaluation Guide		Low	FY05	250		
7.2.4	Cost-Beneift Analysis of ITS Technologies Application to BRT Stages		Low	FY06	250		
7.3.1	Ongoing Transit ITS Projects	10.15, 10.18, 10.25	ACTION		-	-	Project 4.08
7.3.2	Sketch Planning nad Parametric Analysis Techniques	10.14, 10.18, 10.15	ACTION		-	-	Project 4.08
7.3.3	NGSIM	10.17	ACTION		-	-	Project 4.08
7.3.4	FTA New Starts Process and BRT	8.05	ACTION		-	-	Project 4.08
BRT-ITS Outreach and Training							
8.2.1	BRT-ITS Technical Implementation Workshop		High	FY04	75		
8.2.2	BRT-ITS Planning Guide		High	FY04	150		
8.2.3	BRT-ITS Operation Policies/Protocols and Training Course		Low	FY05	200		
8.2.4	International Experience with BRT with Comprehensive Coverage	4.10	Low	FY06	250		
8.3.1	BRT-ITS Training	12.01b	ACTION		100	JPO	FY02 RA

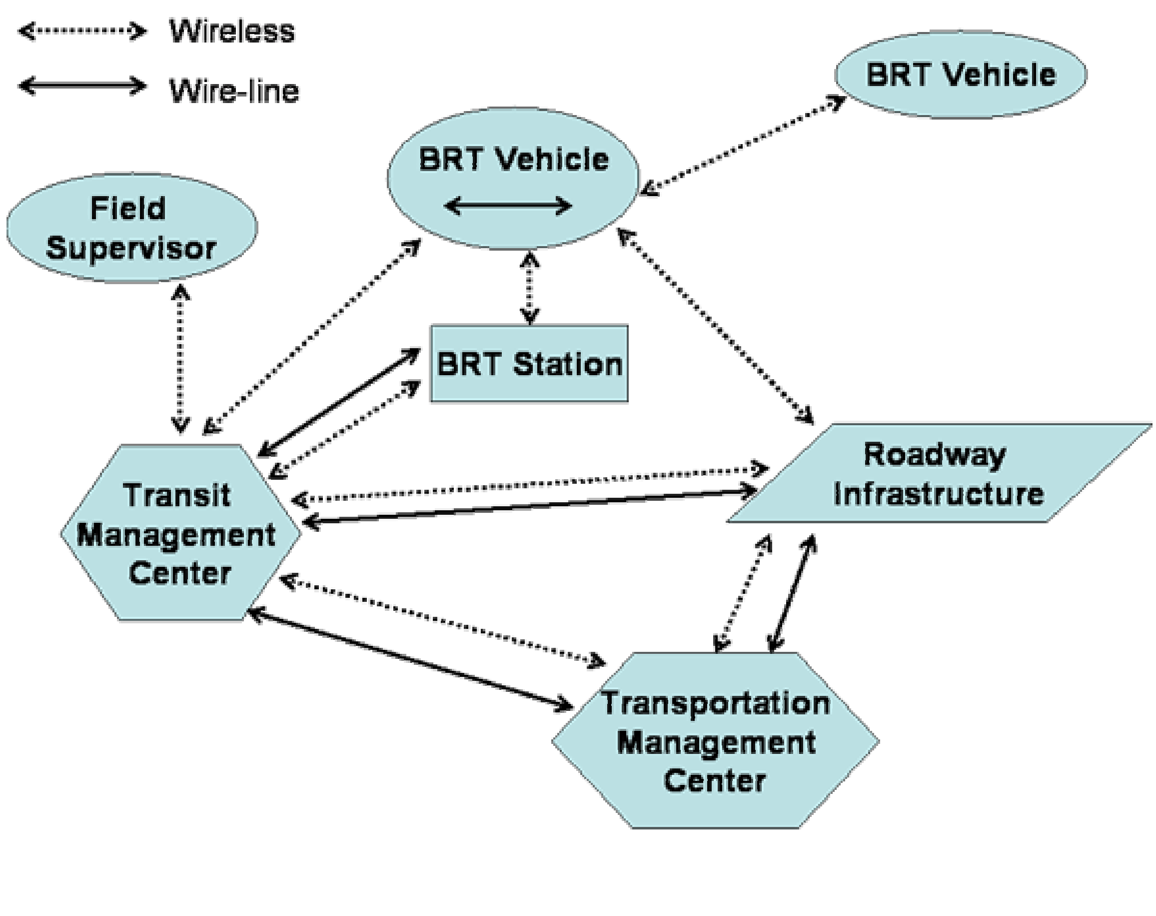
FY02 RA : Project has been identified for funding within the FTA/JPO Fiscal Year 2002 Reimbursable Agreement
FY03 RA : Project has been identified for funding within the FTA/JPO Fiscal Year 2003 Reimbursable Agreement
Request for FY04/05 : Proeject has been identified within the FTA ITS Program Plan for funding in Fiscal Year 2004 or 2005
Project 4.08 : Action items can be addressed by BRT-ITS Support Project 4.08 in Fiscal Year 2003 or 2004

2.0 BRT Systems Integration

The ITS-Enhanced BRT white paper shows that the successful deployment of a BRT system is predicated on the utilization of ITS technologies. Additionally, ITS technologies require the utilization of a robust communication system, either via wire-line or wireless, to transmit data and create an integrated system. Therefore, it is imperative that BRT sites have an Advanced Communication System (ACS) designed to meet the needs of the ITS technologies they plan to deploy and any future technology utilization to have an integrated BRT systems.

An ACS is not focused purely upon the communications between the BRT vehicle and the TMC. While this is a vital data link, it is just one of the many communication links required for BRT system integration. Figure 2.1 provides a schematic of a typical communication system and the interactions between the various components of BRT system.

Figure 2.1 BRT Communication Schematic



As is evident in the BRT-ITS Hierarchy presented in the ITS-Enhanced BRT White Paper, an ACS is at the foundation of a successfully deployed ITS-enhanced BRT system. All of the 21

ITS technologies require some form of communication among the BRT vehicle, roadside infrastructure and transit management center. Therefore, in order to have a successfully deployed BRT system, a BRT site must have an ACS that allows for the integration of the various ITS technologies. The ACS essentially provides the means for the synergies of the ITS technologies and BRT concept to come together.

Many of the ITS technologies presented in this white paper have not been implemented by many of the BRT sites. In some cases it was due to lack of funding and in others because they were beyond the capabilities of their current communications system. In a few cases the BRT system became an impetus for installing a new communication system. For example, the Metro Rapid system in Los Angeles needed some means to transmit data between the BRT vehicle, traffic signal and transit management center in order to implement the TSP system. Because of Metro Rapid, fiber optic cables were installed linking the traffic signal and the TMC. However, in some instances the transit agency implementation of the devices that collect transit data, such as fare box contents and engine status information, do not provide the necessary communications interface to retrieve this data in real-time. Rather, the data is collected on some form of storage media or the utilization of a proprietary diagnostic tool for end-of-shift archiving and analysis.

BRT sites need to analyze communication needs of the ITS technologies and compare them to current communication capabilities. Currently, for BRT vehicle to Transit Management Center communication, transit agencies rely on traditional communication means that include analog and digital radio systems:

- Land mobile radio systems in the public safety spectrum
- Specialized mobile radio systems such as:
    - Analog systems at 150, 450 MHz bands
    - Digital, trunked systems in the 150, 450 MHz bands
    - Digital, trunked systems in the 800 MHz band (transit owned)
    - Digital, trunked, 800 MHz system (transit partner in state or local government group)
- Proprietary Systems such as Mobilenet's Voice-over IP
- Commercial Service such as CDPD

In some FTA documents these types of radio systems are considered to be an ACS. However, their band width and communication capacity may be exceeded by the additional data and information update frequency required by the advanced operations that are part of the different stages of BRT. For example, typical AVL systems for overall system operations poll for location and other every 60 to 120 seconds. BRT operations with signal priority, operator lane assist, reduced headways between vehicles, and real time information may need both more frequent updates and more types of data than normal operations. With the extensive data needs of an ITS-enhanced BRT system, the existing communications systems may very well fall short of providing the necessary bandwidth and speed required for the ITS technologies.

Currently, many transit agencies and BRT sites have had to modify their existing communication system in order to handle the most basic data needs of AVL systems and Mobile Data Terminals. Some of the other communication needs, such as Transit Management Center to Transportation Management Center or the Roadway Infrastructure to Transportation Management Center have not been addressed. These needs are often put together in an ad-hoc manner to address current requirements without looking at future needs and limitations. To address this, an important research component will be the tradeoff between a BRT only deployment and a system-wide deployment.

Already there is some research into the next generation of communication systems. These services can be categorized as Commercial Mobile Radio Systems and include services such as CDPD, Cellemetry (both used by some transit agencies), CDMA-based service, GSM-based services and Digital SMR. All of these services are explained in greater detail in the report "Commercial Mobile Radio Systems Applications in Public Transit", MTS, February 2003 (draft).

2.1 Current Research and Products

- **Commercial Mobile Radio Systems Applications in Public Transit**—Current Mitretek research that focuses on the reliability of the commercially provided service, coverage and cost. It also addresses the coming changes in frequency spectrum allocation that will have an impact on transit communications. It will also provide an update on FCC frequency allocation issues.
  Status: Phase I Report (draft) available March 2003
- **Spectrum Management Issues for the Federal Transit Administration**—Research conducted by Mitretek examining major spectrum management issues.
  Status: completed
- **FTA Security Design Research Program**—Proposed management and work plan submitted by Volpe. Includes proposed research into the security of transit communication needs which may be applicable to BRT operations.
  Status: active

- **Impact of Radio Frequency Refarming on Transit Communication**—TCRP report that examines the issues surrounding the FCC rules governing the refarming the land mobile radio spectrum.
  Status: active

2.2 Potential Projects

Clearly, BRT sites need to understand the complexities of the ACS and begin to address the needs of their BRT system and how an ACS will allow their BRT system to be a success. There are other options for deploying an ACS that have been researched and documented. There is ample technical information available on planning, designing and acquiring traditional transit communication systems. This primarily includes land mobile radio systems used for voice dispatch with some limited data applications usually pertaining to AVL and operations management. There is little, if any, documentation outlining the full set of communication requirements for a BRT system at the four stages of deployment. In addition, the current data rate limitation of current land mobile radio systems limit the functions critical to successful BRT deployment, such as accessing security video en-route, viewing engine diagnostics data, remote programming of traveler information signs, and downloading schedules to BRT vehicles pressed into service due to accidents and breakdowns.

To address these needs, five projects are recommended:

1) Communication Requirements for Successful BRT System Integration
2) Advanced Communication System Cost
3) BRT Vehicle Systems Integration
4) BRT System Procurement and Evaluation Guidelines for ITS Technologies
5) Application of Commercial Digital Wireless Data Service on the BRT Vehicle

The first project focuses on overall communication requirements. In addition the project will address the communication needs of each of the 21 ITS technologies. The second project will address the cost to design and install ACS and focus on the incremental cost and benefits of an ACS. The third project focus upon the BRT vehicle itself and how to integrate multiple technologies. The fourth project will develop overall procure and evaluation guidelines for an integrated BRT system. Finally, the fifth project will focus upon the communication link between the BRT vehicle and the TMC. This research can build upon previously completed and ongoing research presented in Section 2.1.

2.2.1 BRT Vehicle Systems Integration

Initially, this study will examine the requirements and methods of integrating multiple data sources on a BRT vehicle. This will include the VAN standards development (data-bus, wireless network, LAN, etc.) and additional requirements as needed. Second, various BRT-ITS technologies will be integrated onto an operational vehicle in a controlled environment to assess data output under various operational scenarios. Finally, the technologies will deployed in a real-world operation for demonstration and evaluation purposes among the four BRT deployment stages.

Referenced from FTA Transit ITS Program Plan Project 4.13, FY 2003 and Project 4.14.

2.2.2 Communication Requirements for Successful BRT System Integration

This project will focus upon the overall communication needs (both wireless and wireline) for the four stages of BRT systems (see Figure 2.1). For vehicle communications a single information pipe from the TMC to the vehicle is the ultimate goal. The increased ITS data communication needs at BRT sites must be coordinated and integrated with other transit system requirements. An appropriate first step is to determine what ITS technologies need to be integrated at the site and then decide on a communication system based upon these requirements while taking into account the initial deployment stage (I-IV) and the ultimate deployment stage (I-IV). In some cases the operating environment (such as a separate right-of-way) may afford more opportunities for communication. Examples of these requirements include:

- **BRT Vehicle to Transit Mgmt. Center**—Wireless link to handle voice, data, and video in order for all of the necessary technologies (Silent Alarms, Voice and Video Monitoring, Vehicle Tracking, Electronic Fare Collection, Vehicle Mechanical Monitoring and Maintenance). ACS utilization includes modern radio communication such as commercial wireless services, digital radio or CDPD.
- **BRT Vehicle to BRT Vehicle**—Wireless link to handle electronic coupling and other BRT automation functions. ACS utilization includes DSRC technologies.
- **BRT Vehicle to Roadway Infrastructure**—Wireless link to handle precision docking and other BRT automation functions, transit signal priority, and station/lane access control. ACS utilization includes DSRC technologies.
- **Transit Mgmt. Center to Transportation Mgmt. Center**—Wireline or wireless link for sharing of data; such as the transit signal priority system. ACS utilization includes fiber optic cable.
- **Transit Mgmt. Center to BRT Station**—Wireline or wireless link for dissemination of transfer. ACS utilization may be fiber optic cable or modern radio communication system.

- **Roadway Infrastructure to Transit/Transportation Mgmt. Center**—Wireline or wireless link to handle transit signal priority system. ACS utilization may include fiber optic cable or modern radio communication system.

2.2.3 Advanced Communication System Cost

This research will examine the issue of fixed and variable costs associated with communication requirements. For example, if a new ACS is required for a certain BRT route, does it make better financial sense to install a new ACS for the entire transit system or do the incremental costs of expanding an ACS warrant a piece-meal approach? Also, this research will look into the tradeoffs and options available for designing an ACS for BRT operations versus system-wide implementation.

2.2.4 BRT Technology Procurement Guidelines

The capability of ITS technologies is largely subject to the availability of other ITS technologies that play supporting roles in generating/delivering the desired advanced traveler information. For instance, the provision of real-time BRT arrival estimates at stations/wayside locations relies on the system's capability to 1) track vehicle locations (e.g., AVL) and 2) communicate real-time data between mobile (vehicles) and fixed (control center and wayside) sources.

With the support from the BRT consortium and the BRT institute, this study will initially focus on System Planning and Procurement Guide. This document may include logical sequencing of deployment and integration of ITS technologies, hardware and software requirements associated with different BRT system architecture, related ITS standards, technology functional specification languages, and guide to selection of appropriate ITS technology options (e.g., communication media and devices, types of information, etc.) under different operating scenarios.

The goal of this study is to provide a cost-conscious visioning tool that can guide transit agencies toward a logical incremental deployment of BRT-ITS that best meets their needs based on available/limited resources. The outcomes of the study should not only provide guidance to agencies that consider deploying BRT-ITS technologies in phases, but also support agencies that plan to incorporate BRT with other existing ITS components.

2.2.5 Application of Commercial Digital Wireless Data Service to Transit

With the emergence of the next generation of commercial mobile radio systems wireless services, the potential for BRT systems to realize the full benefit of ITS technologies is greatly enhanced. These systems include data services of 144 kilobits per second (kbps) for mobile terminals (vehicles) at highway speed and higher rates for stationary terminals. This type of service supports an integrated communication system that includes silent alarms, voice and video monitoring, AVL, vehicle mechanical monitoring and maintenance systems, and EFC all transmitted over that same communications link. This research topic will build on the completed and ongoing CY03 research to examine the availability of these services, selection of requirements, and provide recommendations on how BRT system operators can integrate wireless data services into their overall advanced communication system.

3.0 Electronic Fare Collection for BRT Systems

Electronic Fare Collection is seen as a high priority technology for BRT sites to implement since it provides primary benefits to BRT travelers, operators and management. Most of the BRT sites that are currently in operation and those in the planning process have expressed an intension to implement some form of Electronic Fare Collection. However, none of the BRT sites currently in operation have an Electronic Fare Collection system. Electronic Fare Collection has the potential to significantly reduce overall travel time (rapid boarding), and improve the efficiency (reduce costs) of the back-office operations that support fare collection and handling.

Electronic fare collection can be utilized in a number of fare collection environments. There are four strategies that can be considered for BRT systems wanting to utilize Electronic Fare Collection:

- **Self-Service Barrier-Free**—Also known as Proof-of-Payment (POP). Use electronic media to purchase ticket, or use to validate farecard-or have pass where inspectors need hand-held readers. Most common in Europe and some U.S. light rail operations.
- **Barrier**—Faregates read farecard and deduct value-or indicate a valid pass. Most typical of U.S. heavy rail operations. Also used in some foreign BRT operations such as Curitiba, Brazil and in a few North America bus operations in Seattle, WA and Canada.
- **Conductor-Validated**—Conductors need hand-held farecard readers/processing units. Common on commuter rail operations.
- **Pay on Boarding**—Need ticket processing units/card readers on the BRT vehicle. Typical of current U.S. bus operations.

Although each strategy offers certain advantages over the others the most significant factors to consider are: 1) the station or platform configuration and constraints and 2) the expected passenger volume. In much of the BRT research currently available, it is apparent that a self-service barrier-free system is preferred. However, this type of system is not typically used in North America; except for a handful of light-rail operations, let alone BRT operations. Self-service barrier-free operation provide two primary operational benefits: passholders can board through any door; and fare collection is taken off the BRT vehicle to decrease station dwell time. In other words, self-service barrier-free is preferred since BRT stations and stops will be in an environment featuring open platforms, many at or near street level. Ultimately, the selection of fare collection strategy will be based upon the tradeoff between ITS technology, physical design, vehicle design and service operations within the BRT operations corridor and station area. Other options include a barrier system if it is possible to install faregates and establish a clearly defined paid area, or a pay on boarding method.

3.1 Current Research and Products

- **O.R.A.N.G.E.S. Operational Test**—Orlando Regional Alliance for Next Generation Electronic Payment Systems operational test and evaluation of a multi-modal electronic payment system that integrates transit fare collection, parking payment, and toll collection into a single system.
  Status: active
- **Delaware Smart Card Operational Test**—Develop a statewide transportation payment system through incremental steps, beginning with transit payment system partnerships. The test will identify and help resolve institutional issues (integration and operational problems) among multiple organizations, and will demonstrate the feasibility of implementing a statewide EP system within a small state.
  Status: active
- **ITS America Electronic Payment Task Force**—An ITS America industry group that promotes transportation electronic payment interoperability. Published "Introduction to Electronic Payment Systems and Transportation," April, 2001.
  Status: active
- **A Toolkit for Self-Service, Barrier-Free Fare Collection**—Software tool developed for FTA to provide urban transit officials with a tool to internally evaluate fare revenue control measures.
  Status: completed
- **Fare Revenue Interactive Electronic Workbook**—TCRP Project A-24. A set of guidelines for use by those transit agencies implementing or considering self-service, barrier-free fare collection. Topics covered include: Policy and enforcement issues, operational issues, and capital and equipment issues.
  Status: completed
- **Central Light Rail Line Fare Validation Study**—Study conducted for the Maryland Mass Transit Administration that evaluated the effectiveness of the current fare collection procedures on the Central Light Rail Line and compare its effectiveness against other rail transit systems. Also assessed the feasibility of implementing a barrier system on the Central Light Rail Line.
  Status: completed
- **Universal Transit Farecard Standards Program**—Produces a set of documents that provides industry guidance for the creation of an open architecture electronic payment

environment and provide a platform to support agency independence and vendor neutrality.
Status: active

- **National Transit Smart Card Guideline**—Guidelines developed for FTA to assist localities in the deployment of regional smart card systems.
  Status: completed
- **Regional Fare Management Programs Scoping Study**—TCRP Project J-6. Analysis of cooperative efforts that have resulted in multi-agency fare systems. Tasks include reviewing features, processes and issues affecting regional fare management programs.
  Status: completed

3.2 Recommendations

There is currently volumes of research, documents, and real-world deployments of electronic fare collection systems in different operating environments. Much of this experience can be applied to BRT systems. BRT is unique in that it is not a rail system where station-based fare collection is generally used or a bus system where vehicle-based fare collection is used. Much of the research will focus upon the underlying tradeoff among ITS technology, physical design, vehicle design and service operations. These design parameters, along with the four BRT deployment stages, may have an overriding influence on what is practical and what is impractical.

3.2.1 Implementation Guidelines for BRT Fare Collection

BRT has the potential to be a hybrid system utilizing both station and vehicle-based systems within a proof-of-payment environment. There needs to be an understanding of the different circumstances where a station-based fare collection should be used or a vehicle-based fare collection should be used or the blending of the two. Also, there will be a tradeoff between the technology utilized, vehicle design, physical layout of the system and the service operations that will impact the design and operation of a BRT fare collection system. In addition, the Stage at which a particular BRT site is at will have an impact of system design. This research will examine the blending of electronic fare collection and various fare collection strategies to develop guidance for BRT sites.

3.2.2 On-Site Technical Support for EFP System Implementation

Technical support needs to be provided to all BRT sites currently in operation on how they could implement Electronic Fare Collection systems based on the guidelines developed and to work with all BRT sites currently in the planning process to encourage them to implement an Electronic Fare Collection.

3.2.3 Multi-application Electronic Payment Systems

This activity will facilitate and evaluate the implementation of universal multi-application electronic payment systems that integrate the payment systems of transportation and non-transportation service providers into a single system. Initial implementations will identify and help resolve institutional issues (integration and operational problems) among multiple organizations, and will demonstrate the feasibility of open, multi-application electronic payment systems (clearinghouse function).

Referenced from FTA Transit ITS Program Plan Project 3.07, FY 2004.

4.0 Transit Signal Priority: Adapted to the BRT Operating Environment

Transit signal priority (TSP) is identified as a key feature that enable BRT systems to attain the characteristics of rail rapid transit system (e.g., minimum delays and service reliability) with substantially lower cost in capital investment, while preserving the flexibility of bus transit. In essence, TSP is an ITS technology that provides in-service transit vehicles at signalized intersections with favorable treatment over other road users by adjusting signal timing and/or phasing, such as green phase extension or phase rotation. The intent is not only to reduce the overall traffic signal delays (thus greater operating speed and shortened travel time) of in-service transit vehicles, but also to achieve greater schedule/headway adherence and consistency (thus enhanced reliability, short wait). Empirical evidence shows that the deployment of TSP has resulted in substantial (averaging 15%) transit travel time savings and only minor impacts on the cross street traffic (ITSA, 2002). Service reliability improvements (such as schedule adherence) have also been reported in Seattle Washington (20% improvement in AM travel time standard deviation), Portland Oregon (9% improvement in on-time performance), and Vancouver, British Columbia (29% improvements in AM and 59% improvements in PM on-time performance) among others.

There are several possible types of traffic signal priority treatments applicable to transit, ranging from the simplest passive priority to the most sophisticated adaptive/real-time control. These TSP strategies vary widely in their benefits and costs, applicability as well as limitations. A recent document published by ITS America, *An Overview of Transit Signal Priority*, jointly sponsored by the ITS America ATMS and ITS America/APTA APTS committee, provides an introductory overview of TSP related issues.

The concept of TSP is not unique to BRT. According to *Advanced Public Transportation Systems Deployment in the United States Year 2000 Update*, there is an 87% increase in the numbers of transit agencies with operational TSP systems from year 1998 (16 agencies) to year 2000 (30 agencies). New and rapid advances in traffic/bus detection and communication technologies, and well-defined priority algorithms have made TSP more appealing or acceptable to more road users of all modes. When combined with reserved right-of-way or queue jumping in the BRT design, TSP may yield multiplying positive impacts on achieving system performance goals, especially in terms of travel speed and service reliability, and thus make BRT far more appealing to the traveling public. In fact, TSP appears to be one of the most popular ITS technologies deployed in the BRT environment. Seventeen of twenty-one (81%) BRT sites reportedly are implementing or planning TSP in their BRT systems.

The implementation of TSP cannot be accomplished without full cooperation and coordination from traffic management authorities and all agencies or individuals who will be affected by the project. Most transit agencies have neither jurisdiction nor adequate field operation knowledge over traffic control devices, including signals and signs and pavement markings. TSP also results in impacts on other road users as well as traffic system operations as a whole, such as possible increase in non-transit vehicle delays. All stakeholders need to be involved throughout the project to assure that the system performance outcomes are consistent with project goals and objectives.

4.1 Current Research and Products

TSP plays a key role in the Federal Transit Administration's BRT initiative. There are a number of federally funded research projects, initiatives and products concerning TSP. These include:

- **JPO/FTA ITS Transit project on Transit Signal Priority Control Strategies and Modeling Tools (Transit ITS Program Plan Project 1.13)—**This project will assess the transit industry needs for incorporating TSP across different forms of public transit systems, including BRT, and then develop modeling tools, control strategies, and/or guidance to help address those needs. As part of this project, four TSP workshops are planned in 2003. The first workshop will focus on identifying research needs and obtaining feedback on the ITS America "An Overview of Transit Signal Priority" white paper released in the Fall of 2002. The recommended research needs will propose a number of activities that may complement those proposed in the following section.
  Status: active
- **TCRP A-16A Improved Traffic Signal Priority for Transit—**The objective of this project is to develop and test improved transit priority algorithms for traffic signal controllers and systems taking into account various levels of hardware sophistication, operating characteristics, and transportation management strategies. The major products of this project will be a description of the algorithms, an evaluation of their associated benefits and effects, and a detailed implementation plan.
  Status: draft final report under oversight panel review and revision
- **SmartBRT—**This project is under the joint sponsorship of FTA and Caltrans to develop a simulation and visualization software specifically to capture BRT infrastructure and operation concepts. TSP is incorporated into this model as an available BRT operational strategy whose effects on the system performance can be estimated by the dynamic modeling process. *Also referenced in Section 7.1 Development of BRT Models.*
  Status: anticipated completion 2003

- **Federally Sponsored University Research**—Additional research on simulation and development of new algorithms is ongoing at both MIT and the Virginia Institute of Technology.
  Status: ongoing

4.2 Project Recommendations

The deployment of TSP has been growing rapidly over the last few years. It is also one of the most popular ITS technologies proposed for many BRT systems under planning and design stage nationwide. Evaluations on and lessons learned from several empirical deployment experiences, both domestic and internationally, have proven the concept of TSP in a transit setting and provided much needed knowledge for both transit as well as traffic professionals. However, the scale of TSP deployment up to date for bus operations in general, or BRT in particular, has been limited on a corridor by corridor basis. This leaves questions largely unanswered on the planning and design details, as well as implications of TSP deployment on a system-wide basis. In addition, the need is called for effective avenues, such as technical workshops and peer-to-peer assistance programs, through which BRT stakeholders, both public and private, can disseminate and share information.

4.2.1 TSP Deployment Case Studies

- **Applicability of Los Angeles Metro Rapid software to Multiple BRT Site**
  The Transit Priority Systems (TPS) implemented by the Los Angeles Metro Rapid Bus Demonstration Program along major transit corridors has been successful and resulted in substantial transit time savings and improvement in schedule adherence. The Transit Priority Manager (TPM) program is the core in the system that provides transit priority on a network basis to balance the needs for right-of-way between transit vehicles and general traffic. This project will evaluate the extent to which this TPM software and the hardware required to support it can be applied to other BRT sites.
  Referenced from FTA Transit ITS Program Plan Project 4.09 dropped June 2002.
- **International Review of TSP Deployment/Technologies and Their Potential Use in the U.S.**
  TSP has been more widespread in some parts of the world, such as Europe, than in the United States. While many aspects of traffic operations differ from country to country, some TSP technologies and lessons drawn from such international TSP deployment experiences may still be of interest to BRT systems in the United States. For example, the European Bus Priority Strategies and Impact Scenarios Developed On A Large Urban Area (Priscilla) is a pooled European Commission Effort that is investigating advanced transit priority as an integral part of ATMS systems. They recently completed an international state-of-the-art review that may be useful to U.S. systems. USDOT may

take the lead to facilitate periodic reviews of international TSP deployment as well as technological development, and examine their applicability in the United States.
Referenced from FTA Transit ITS Program Plan Project 4.10, FY 04.

4.2.2 System-wide TSP and BRT: Priority Conflict Resolution for Multiple BRT Corridor(s)

So far, all operational TSP systems in the US are on a corridor by corridor basis. That is, priority is given only to in-service transit vehicles traveling on a single transit priority corridor with all crossing streets yielding their right-of-way when TSP is activated. Consequently, benefits/costs outcomes derived from these filed operations, such as minor impacts to cross-streets traffic, may not be applicable to a more complex BRT operating environment where multiple traffic signal priority corridors cross each other. There is a need for BRT industry to explore TSP operational issues, ranging from control algorithm and logic to traffic operation impacts, for parallel and cross corridor situations or even for a network-wide TSP deployment.

4.2.3 Cross-Cutting Assessment of TSP Impacts on BRT Operations

TSP is being included in a majority of the BRT projects funded by the FTA BRT program, and is also a key element in many others. This project will provide a cross cutting assessment of the BRT and TSP experiences to determine what type of TSP is appropriate for the different stages of BRT under different operating conditions. Service reliability, most importantly schedule and headway adherence, is one of the dominant factors in affecting customer satisfaction and their ratings on transit service quality. One BRT priority strategy is to give priority only to late buses (compared to the scheduled time) but not to early buses. This strategy optimizes schedule adherence (and therefore minimizes waiting time) rather than shortening travel time. The additional changes to service, physical, and vehicle design such as stop location, frequency of busses, bus bulb design, and base signal timing plans have also not been evaluated in conjunction with different types of BRT or TSP algorithms.

Also, empirical evidence has found a relatively wide range of benefits associated with the deployment of TSP. For instance, TSP deployment in Minneapolis, MN on bus operations experienced 0 to 38% in bus travel times depending on TSP strategy. Different TSP strategies will likely produce varying effects on system performance based on different BRT operational goals as well as the external operating environment. Research is needed to identify these factors and quantify their potential impacts on the effectiveness of TSP under different scenarios. The results of this research should be used as a reference in preparation of a guide to selection of appropriate TSP implementation options under different operating scenarios. . It will also provide guidance on how to effectively deploy TSP within BRT environments and suggestions on concomitant changes to service, physical, and vehicle design required to take advantage of TSP.

4.2.4 Field Operational Tests and Evaluation of Transit Signal Priority Algorithms

Currently there are numerous transit signal priority algorithms suitable for different traffic operational scenarios. There are also a number of advanced signal system and transit priority algorithms currently being developed or deployed in Europe. These results can be used to inform interested local jurisdictions, in conjunction with traffic signal system vendors, about the opportunity to operationally test the viability of these priority algorithms. USDOT should consider providing seed money as an incentive to offset additional project development costs and encouraging such trials.

4.3 Other Recommended Actions

4.3.1 TSP Deployment Experience Survey

As Transit Signal Priority systems are being deployed across the U.S. one common theme that is emerging is that designing, implementing and operating a TSP system that provides the hoped for service improvements and benefits is not as simple as it originally seemed. Signal priority is a complex service that requires close coordination of traffic and transit systems, communications, and operations. Issues and hurdles that have developed concern the supporting design of transit facilities and service, location of stops, integration of software and controller logic, unforeseen events and traffic/transit situations, reliable communications, and others.

It is recommended that the Advanced Public Transportation Systems Deployment in the United States, a bi-annual publication traditionally prepared by the Volpe National Transportation Systems Center for FTA in conjunction with Oak Ridge National Laboratory (under a separate contract with JPO), should begin incorporating BRT/TSP deployment status in the next release. This should be accompanied by a one time set of additional questions focused on TSP and BRT implementation issues where it is found that TSP is either deployed or in the process of being implemented. Questions regarding the details of the priority implementation, the transit service and traffic conditions, under which it operates, the issues encountered during implementation, and how they were resolved shall be included.

4.3.2 Transit Signal Priority Control Strategies and Modeling Tools

The planned TSP workshops being carried out as part of the ITS Transit Project 1.13 may cover many of the subjects related to TSP/BRT. Coordination should occur to insure that the topics, agendas, and locations for these workshops incorporate BRT-related issues and concerns. The

FTA should encourage BRT site representatives to attend these workshops. The results of the workshops should be consolidated and disseminated to BRT sites.

4.3.3 TSP Peer-to-Peer Technical Assistance

As stated, many system integration and implementation issues have arisen in recent TSP applications as systems move from theroretical design to actual operations. This project would provide the opportunity for peer-to-peer exchange to share experiences and help in deployment issues. It may also provide direct technical assistance using on-call teams of experts that may be able to assist in specific technical problems as they arise. Such an initiative may be particularly useful during this time of BRT program development when the knowledge base built upon actual BRT/TSP field deployment experiences is limited, and yet rapidly growing.

5.0 BRT System Automation

BRT Automation (also referred to as IVI technologies) can maximize the capacity and amenity value of BRT vehicles by minimizing the need for dedicated bus lanes. These automation functions include precision docking, lane keeping, automated speed and headway control and maintenance yard operations. The activities conducted under the IVI program emphasize problem areas such as rear-end collisions, roadway departure collisions, lane change and merge collisions, and intersection collisions. Potential countermeasures for these problem areas include vehicle-based and vehicle-infrastructure cooperative communication systems. Research is being conducted to develop performance guidelines, specifications, objective test procedures, architectures, and standards, and will test and evaluate the safety impact of the most promising configurations.

The first generation BRT Automation technologies include Collision Warning Devices, Lane Assist Technology, and Precision Docking. The next generation may include platooning of BRT vehicles and collision avoidance systems. All of these technologies will provide transit passengers with reduced travel time, improved trip time reliability, enhanced access to and from buses for mobility impaired passengers and reduce time for loading and unloading. Automated control will improve ride comfort by reducing the frequency of stops and smoothing ride. The need to transfer buses will be reduced because buses may be able to operate on collection and distribution and line haul operations.

5.1 Current Research and Products

- **Application of IVI Technologies for BRT Systems**—Paper explores the application of Intelligent Vehicle Initiative (IVI) technologies to BRT systems that will help mitigate the safety concerns associated with BRT operations.
  Status: completed
- **Lane Change Collision Warning**—Operational test to develop and assess vehicle performance specifications for lane change. The project includes the installation and testing of prototype system in Pittsburgh, PA.
  Status: active
- **Rear End Collision Warning—**Operational test to develop and assess vehicle performance specifications for rear impact warning systems.
  Status: active

- **Frontal Collision Warning—**Operational test to develop and assess vehicle performance specifications for front collision warning systems. Project participants include CalTrans/SamTrans and PATH.
  Status: active
- **Heads-Up Display for Collision Warning**
- **Integrated Collision Warning System**—Follows on earlier research calling for the integration of Forward and Lane Change Collision Warning Systems. This project will enhance human factors elements.
  Status: active
- **BRT Automation Phase I: Lane Assist for BRT (Transit ITS Program Plan Project 7.08)**—Determine requirements for lane assist systems and any available technologies. Will compare lane assist technologies for precision docking and identify human factors. The final product will be a system requirements report.
  Status: active

5.2 Recommendations

Currently few BRT sites have implemented IVI technologies or are planning to implement them. However, many of the automation functions presented in the ITS Enhanced BRT White Paper have the potential to significantly improve BRT operations. Therefore, it is important that BRT sites consider these technologies; especially those sites operating in unique environments such as narrow lanes or road shoulders.

5.2.1 BRT Automation Phase II: Operational Tests of Lane Assist Requirements

Under the IVI program a project was initiated to define lane assist requirements for BRT vehicles operating in narrow lanes. This may increase the ability to implement dedicated rights of way for BRT operations. This follow-on project will take the requirements developed as part of the Lane Assist for BRT and test them in various operational scenarios. Operational scenarios should include various roadway operations (interstate vs. local streets) and weather differences (hot climates vs. cold). Based on the required functions, the project team will design the vehicle and infrastructure lane assist systems. The project will integrate sensor system, steering controller, steering actuator, driver interface, roadside-to-vehicle communication system, and system diagnostics.
Referenced from FTA Transit ITS Program Plan Project 7.08, Phase II, FY 2004.

5.2.2 BRT Automation Phase II: Precision Docking

Requirements, available technology and current case studies

5.2.3 BRT Automation Phase II: Assessment of Human Factors, Safety & Liability Risks

of BRT Automation

This human factors study will examine driver behavior and acceptance of automated systems. Examine various safety elements of single and combined IVI technologies to insure they will improve operations while not decreasing the safety of bus operations. This study will also help provide transit agencies with an understanding of the liability issues associated with BRT automation and procedures for overcoming any liability-based obstacles to deployment.

5.2.4 BRT Automation Phase II: Reliability, Availability & Maintainability of BRT Automation Technologies

This study will examine how reliable various IVI technologies area. This effort will also look into the availability and maintainability of these technologies.

5.2.5 European Information Exchange

It is evident that many BRT sites are interested in utilizing some of the European vehicle designs that are currently available. Examples include Las Vegas, NV acquiring the CIVIS Vehicle out of France and Eugene, Oregon expressing interest in the Philleas Vehicle out of Holland. Clearly, the European manufacturers have something that U.S. transit properties want. An exchange program could provide needed information sharing between European transit professionals and U.S. transit professionals. This could be accomplished through the FTA International Program utilizing signed information sharing memorandums as is currently available with the U.S. DOT and the Dutch Ministry of Transport.
Referenced from FTA Transit ITS Program Plan Project 4.10, FY 04.

5.2.6 BRT Automation Phase III: Vehicle Platooning Technologies

Study to examine the feasibility, need, technological requirements of electronically coupling BRT vehicles for line-haul operations.

6.0 ATIS in Support of BRT

The provision of transit information to travelers is a very important element of transit service operations. Traveler information plays a key role in defining transit service quality, affecting customer satisfaction, and even shaping public perception toward public transportation. Empirical evidence has demonstrated positive associations between transit ridership and traveler access to transit information (Abdel-Aty, M. A., 2001; Syed, S. J. and Khan, A. M., 2000). To improve the transit experience and subsequently increase ridership, transit agencies are attempting to meet customers' information needs in a number of ways, including through the use of Transit Intelligent Information Systems.

Traditionally transit agencies provide traveler information through printed hard copy materials (e.g., riders' guide with route map, fare, and bus schedule) and customer service telephone lines. Today's customers are expecting more and better transit information. Recent advances in ITS technologies related to communication and vehicle tracking have afforded transit operators to deliver advanced traveler information to their (potential) customers in a more efficient and effective manner.

Advanced transit traveler information is delivered to customers both per-trip and en-route at various locations via a number of communication instruments (media and devices), including, but not limited to, the following: Internet, electronic kiosks, dynamic message signs, video monitors, in-vehicle annunciators, interactive voice response telephone systems, personal digital assistants, and fax. Currently transit agencies provide numerous types of traveler information via transit ITS, ranging from more static information such as routes, schedules and fares, to more dynamic information, such as real-time bus arrival/departure status, and incident reporting. In recent years, substantial attention has also been directed to the development of intermodal itinerary/trip planning information system that are capable of providing seamless, door-to-door trip itinerary planning support to travelers in real time on a request-by-request basis.

Like many other ITS transit technologies, ATIS issues are not unique to BRT. However, the provision of high quality of traveler information on BRT systems is especially crucial given the fact that BRT is often considered as a potential alternative to the more expensive LRT that usually supports greater quality of traveler information than traditional bus transit services. After all, Advanced Traveler Information Systems (ATIS) for BRT is the front-line ITS showcase which provides direct interface with the traveling public. Studies have found that transit ATIS is not only a service tool which can benefit the travelers with advanced real-time information, but also a marketing tool that is capable of effectively stimulating customer satisfaction and shaping positive imagine and perception about public transportation usage among the general public – a very important instrument to promote BRT.

6.1 Current Research and Products

There are many federally funded current or past research projects, initiatives and products concerning advanced traveler information. These include:

- **Transit Communications Interface Profiles (TCIP) 1403 Passenger Information Business Area Standard (Transit ITS Program Plan Project 9.05)**—The TCIP Passenger Information Business Area Standard has been published and is now available for utilizations by the transit industry. It defines the passenger information data elements (objects) that are supported by the TCIP for passenger customer service. The passenger information domain deals with data needs related to providing passengers with information necessary for planning and taking trips using public transportation. The data element needs that are supported by this standard include data associated with traveler preferences (departure time, arrival time, mode, and costs), expected times of arrival, schedules, and other information related to transit services. The standard also supports transit data element needs of many types of information services, such as customer service information centers, regional traveler information services, and information service providers (ISPs). The information may be supplied to users via the Internet, dynamic message signs, or interactive information kiosks. The passenger information domain relies heavily on the TCIP scheduling business area for support data such as transit schedules and vehicle assignments, and on the TCIP control center business area for real-time travel information.
  Status: completed
- **Traveler Information: American with Disabilities Act (ADA) and Human Factors**—This project examines the effectiveness of transit vehicle electronic signs with respect to ADA requirements. It evaluates text color, and character dynamics type (static, paging, streaming) and speed under daylight, low light, and nighttime conditions for the following scenarios: 1) sign stationary, 2) front sign moving, and 3) side sign moving. The results will be provided in an ADA guidebook.
  Status: active
- **Real-time Transit Information Assessment—**This project identifies and documents promising practices of implementing and operating real-time transit information systems. It also identifies issues and problems of providing real-time transit information and develops solutions to these barriers based on transit operator

experiences. In addition, the project examines current data collection, fusion, and dissemination techniques and methods, as well as transit ATIS infrastructure, business models, and the unique needs of different transit modes. The results will be provided in a guidance document for transit agencies. This project will help transit agencies implement and operate useful/successful real-time transit information systems.
Status: near completion (final due April 2003)

- **ATIS Human Factors—**This project assists transit agencies in providing the information that travelers want and expect. It examines the human factors involved in presenting and displaying transit information, and the impacts of information reliability. The results will be provided in a guidance document for transit agencies. This project will help transit agencies provide information in the most effective and preferred manner from the view point of the customer.
Status: active
- **Door-to-Door Multimodal Trip Planning-Trip Planning Assessment and Steering Group Coordination (Phase 1) (Transit ITS Program Plan Project 2.10a)—**This project provided an assessment of needs and alternative approaches for expanding transit trip itinerary planning systems to include multimodal door-to-door functionality. The results were documented in a state of the practice report, and a multimodal trip planning report that provided future trends in multimodal trip planning systems.
Status: completed
- **Door-to-Door Multimodal Trip Planning - TCIP Passenger Information Extensible Markup Language (XML) Development Proof of Concept (Phase 2) (Transit ITS Program Plan Project 2.10b)—**This project takes the functionality defined in Phase 1 and determines if existing standards activities can support this type of service for nonproprietary exchange. A draft XML schema, which builds on the existing ITS standards work (e.g., Transit Communications Interface Profiles passenger information and scheduling standards), will be developed for this service. This may result in recommendations to change/modify existing standards.
Status: active
- **Transit ITS Impacts on Traveler Behavior Research (Transit ITS Program Plan Project 10.25/2.05)—**The impact of transit ITS services on traveler behavior must be understood before it can be properly captured in analysis and decision tools. These include the impacts of different types of customer information on travelers and their choices; transit ITS on traveler perceptions and knowledge of the system; service reliability and its subsequent impact on travel behavior; the processing times

associated with fare collection and the added convenience of universal fare media on travel behavior; etc. This project will first identify and prioritize these features then research their impacts accordingly. The contractor may be requested to develop a statement of work, as a project deliverable, for the next phase of the project.
Status: RFP

- **TCRP Synthesis SA-14 Real Time Bus Arrival Information Systems—**This synthesis documents the state of the practice in real time bus arrival information systems, including both U.S. and international experience, including survey reports on relevant technical capabilities, agency experience, cost, and bus rider reactions to these information systems. This synthesis also includes a review of the relevant literature and focuses on current practice in the field. Finally, this report conducts interviews with key personnel at agencies that have implemented, or are in the process of implementing these systems.
Status: draft report under review
- **TCRP Project A-20A(2) Strategies for Improved Traveler Information—**The objective of this project is to prepare a summary of existing practice in the area of improved traveler information. The summary will identify traveler information needs, assess the state of the art in information technologies, and prepare a number of case studies in the area of improved traveler information. This project is a continuation of TCRP Project A-20A(1) (performed by Charles River Associates, Inc.).
Status: final report expected February 2003
- **TCRP Project J-09: eTransit, Task 4-Customer Information**—This task will identify and assess the areas in which the Internet can have a psignificant positive impact on providing customer information; review applications and technologies that will advance or impede the use of web-based customer information systems; and identify implementation issues and best practices for providing transit information over the internet.
Status: active
- **Puget Sound Regional Council (PSRC) Household Travel Panel**—This project is a before and after analysis of the effect of the ITS Metropolitan Model Deployment Initiative (MMDI) on ownership and use of ATIS and travel behavior. The PSRC panel was created in 1989 to track household travel behavior over time. The MMDI evaluation program co-funded Wave 7 in 1997 to provide a baseline measure of pre-ITS deployment consumer and travel behavior, and Wave 9 in 2000 to measure changes in behavior following ITS deployment. The analysis is considering issues related to the influence of information on mode shift, route choice, trip timing, and (to the extent feasible) broader lifestyle shifts related to the use of traveler information.

Results from this research will be presented at the TRB meeting in January 2003, and will continue with an analysis of data drawn from the Wave 10 survey administration in 2002-03. It should be noted that there were two transit ATIS projects implemented in the greater Seattle area during the MMDI, and two more projects piloted since then. It should also be noted that the PSRC panel "over-samples" transit riders to ensure sufficient statistical representation of transit riders among panel members.
Status: underway

6.2 Project Recommendations

Lack of information has long been cited as a common impediment to transit usage. It diminishes the attractiveness of transit services when competing with other travel modes for customers. In a time when increasing ridership is being slated as a service goal by the Federal Transit Administration, ATIS should play a key role in promoting BRT as an appealing mode choice. Fortunately, many ITS technologies, such as communications and AVL, have enabled transit operators to provide advanced traveler information that is more timely, accurate and informative.

The potential effects of ATIS on enhancing transit service quality and ridership are especially important to BRT deployment that is seen by many as a viable alternate to the more expensive light rail transit (LRT) systems. Unlike most LRT systems, BRT systems often share the right-of-way with other traffic and thus are subject to a greater degree of uncertainties and more service disruptions. ATIS for BRT can effectively mitigate these disadvantages by providing travelers with more timely, accurate and useful information so that the overall quality of service could be maintained at a higher level than comparable to LRT systems.

Past research efforts and resulting knowledge concerning ATIS in general, or ATIS for BRT in particular, has been largely focused on the technical aspect. That is, the potential of ITS technologies in enabling ATIS. However, collective knowledge and research on system component benefits/costs and the actual effectiveness of ATIS at the disaggregate level (i.e., individual traveler) is relatively limited. To address these unmet needs, the following projects are recommended.

6.2.1 BRT Case Studies of ATIS Applications

This project should describe the state of the practice ATIS applications in a BRT environment (ATIS/BRT), including communications instruments, types of information, associated costs and benefits, along with corresponding system architecture and requirements. The project will survey BRT sites to ensure that they are taking advantage of the latest ITS technologies to deliver traveler information. It may include discussions of field examples of ATIS/BRT application, deployment status and their evaluation outcomes. Empirical implementation and institutional obstacles associated with ATIS/BRT should be documented as well. Additionally, the project should capture the element of "branding" and the role that ATIS will play on "branding" BRT. The TCRP Project A-20A(2) Strategies for Improved Traveler Information may serve as a good starting point for this initiative.

6.3 Other Recommended Actions

The following proposed ATIS demonstrations and operational tests are included in the current Transit ITS Program Plan. It is advised to fund these projects as proposed, and give priorities in the site selection process to regions with operational BRT systems, especially for project 2.10c and 2.04.

6.3.1 APTS Deployment in the United States

It is recommended that the Advanced Public Transportation Systems Deployment in the United States, a bi-annual publication traditionally prepared by the Volpe National Transportation Systems Center for FTA in conjunction with Oak Ridge National Laboratory, should begin incorporating ATIS/BRT deployment status in the future releases. FTA is advised to update ATIS-BRT state-of-the-practice information periodically.

6.3.2 Measurement of ATIS Impacts in BRT Environment

Many past evaluations of ATIS field operational tests and/or deployments to date used direct ATIS performance statistics (e.g., accuracies, reliability, timeliness, etc) and survey research methods to measure changes in customer satisfaction and/or public perception toward transit as surrogate measures of ATIS benefits. There is little doubt that positive customer satisfaction and public perception toward BRT are likely associated with increases in BRT ridership. Nevertheless, the extent to which the provision of ATIS impacts individual traveler behaviors under different BRT service scenarios remains largely unanswered. This shortcoming limits our ability to apply these evaluation results to enhance existing mode choice and modeling/simulation tools to account for the benefits of ATIS. As a result, the net impacts of ATIS/BRT are difficult to quantify in an integrated BRT/ITS environment.

Two concurrent projects: Transit-ITS Program Plan Project 10.25, ITS Impacts on Traveler Behavior Research and the Puget Sound Regional Council Household Travel Panel study, are expected to make positive contributions in advancing our knowledge concerning ATIS impacts on individual traveler behaviors. It is advised that FTA/JPO provides close oversight support to these two projects and assess the need for a separate research project, after the completion of both projects.

6.3.3 Door-to-Door Multimodal Trip Planning – Demonstration (Phase 3) (Transit ITS Program Plan Project 2.10c)

This project will demonstrate a standards-based prototype trip itinerary planning system that is multimodal (transit, traffic, air, parking, etc.) and capable of providing door-to-door instructions (with the transit customer in mind). It may be applied to a metropolitan region or larger, inter-city area. The project will also develop guidelines for the transit community on implementing similar systems.

Status: FY03 proposed

6.3.4 Personalized Transit ATIS Operational Test (Transit ITS Program Plan Project 2.03)

This project is designed to demonstrate and evaluate a standards-based traveler information system that provides personalized, or subscriber based, transit information via personal media, including fixed and mobile devices (e.g., fax, land-line phone, desktop computer, mobile phone, personal digital assistant). It will determine the types of information desired by customers and the most effective delivery methods for the much unknown personalized traveler information market.

Status: FY04 proposed

6.3.5 Transit ATIS Test (Transit ITS Program Plan Project 2.04)

Demonstrate and evaluate a standards-based, system-wide or large scale, real-time transit ATIS system in a metropolitan area. The test shall provide arrival information about bus, rail, and/or ferry, and provide information from multiple transit operators. This project will identify why transit agencies may be resistant to providing real-time information to other agencies and the public. It will also identify integration barriers and complexities and potential solutions to those barriers/complexities.

Status: FY05 proposed

7.0 Evaluation of BRT-ITS Impacts and Development of BRT Analysis Tools

The evaluation of the overall impacts of BRT and specifically the impacts of ITS systems within the BRT implementations should continue on an ongoing basis as the federally funded BRT efforts move from design, to implementation, to operation. The evaluations should be used to provide both lessons learned and guidance on the appropriate combination of technology, vehicle design, physical design, and service concepts to best meet the needs and resources found in each BRT deployment. The information should also be used to develop analysis tools to assist decision makers in both the initial system planning and alternatives analysis for potential BRT corridors, and in the ultimate design and operations of BRT once it is selected. Properly accounting for the contributions and impacts of ITS within both the evaluations and the analysis tools is crucial to the deployment of integrated BRT systems that take full advantage of the opportunities ITS offers.

Two recent studies conducted by researchers at the California PATH Program (University of California at Berkeley) explored the institutional issues surrounding BRT planning and implementation and contained several findings relevant to the BRT model development. In their description of intergovernmental issues, the PATH researchers identified the inherently different and often competing objectives that organizations such as transit agencies and traffic departments might have regarding BRT systems. More specifically, the first study states that, "To have a system that works effectively requires the transit agency to achieve agreement with localities and other agencies on infrastructure, operations, and responsibilities." The report further notes that transit agencies are often regarded as "tenants" of traffic departments' roadways and that BRT planning and implementation requires the cooperation of these organizations.

Transit agencies' status as "tenants" supports the assertion that they will generally be responsible for initiating discussions about BRT development with traffic agencies. In doing so, they would be well served to have done sufficient modeling of a BRT system to communicate which features, including possible traffic flow or infrastructure changes, appear to provide the most benefit to transit customers and operations. Showing an appreciation for, and understanding of, potential traffic impacts would also be important when initiating talks. For example, demonstrating to traffic engineers that conditional signal priority can vastly reduce the impact on the signal system (in terms of reducing the number of priority requests granted) could be crucial in establishing initial cooperation.

A BRT modeling toolbox would increase transit agencies' internal understanding of how advanced technologies might be used in the context of BRT development. Readily interpretable and reasonably "realistic" performance measures would help transit agencies decide whether or not to proceed with BRT development, when and how to initiate coordination efforts with local agencies, and how to manage both internal and external expectations.

7.1 Current Research and Products

- **TCRP Project A-23A: Determining the Cost-Effectiveness of Selected BRT Strategies in Increasing Transit Ridership**—Determine the effectiveness of selected BRT strategies in increasing ridership and the cost of implementing various BRT strategies. And, compare the collected data to assess the overall cost effectiveness of implementing these selected BRT strategies.
- **BRT Evaluation Guidelines (Transit ITS Program Plan Project 4.16)**—Guidelines for planning, implementing, and reporting the findings of an evaluation of a BRT implementation site selected for the FTA BRT Demonstration Program.
  Status: completed
- **Hawaii City Express BRT Evaluation (Transit ITS Program Plan Project 4.17)**—The evaluation team intends to perform their evaluation in accordance with the BRT Evaluation Guidelines developed by the Volpe Center. To date, the only known results are that ridership has met the City and County of Honolulu's expectations, and that the service is viewed as a "success" by the residents. Two additional routes to the one originally proposed for the BRT Demonstration Program have been implemented, based on the popularity of the first.
  Status: unknown
- **Los Angles Metro Rapid—**Los Angeles County Metropolitan Transit Authority performed a self evaluation on their Transit Priority System. An FTA-sponsored evaluation was approved. The evaluators have performed a partial analysis of the data collected, but the results have not been documented in a draft report. A final report will be developed when funding becomes available.
  Status: Self evaluation complete; FTA-Sponsored Evaluation: unknown
- **South Miami-Dade Busway**— No official BRT/ITS work has been implemented. The South Miami-Dade Busway *Extension* project is the project that will be evaluated. This project will include advanced vehicle location, computer aided dispatch, traveler information, and signal priority, however implementation of the *Extension* project has not started. Funding ($50,000) was approved from FTA to begin planning for an evaluation.
  Status: unknown

- **Pittsburgh West Busway**—The West Busway initiated service in September 2000. The evaluation process started in February 2001, the evaluators used the BRT Evaluation Guidelines as a baseline to develop the evaluation plan, the plan is being implemented, data is being collected and the evaluation will be completed with a final report in February 2003.
  Status: unkown
- **Bus Rapid Transit Simulation Model Research and Development**—Research and development into a concept of operations of a simulation model developed specifically for BRT that would equip planning professional with a tool that reduces the costly overhead associated with a fully-coded, traffic-centric microsimulation models. Utilized the VIISIM traffic simulation program. Developed by Multisystems, Inc.
  Status: completed
- **SmartBRT: A New Simulation Tool to Assess BRT Systems (Transit ITS Program Plan Project 4.18)**—Simulation and evaluation tool developed to capture the characteristics of BRT infrastructure and operation concepts and the interaction between BRT and the rest of the transportation system. Utilizes the Paramics simulation program. Developed by California PATH.
  Status: active

7.2 Recommendations

Many transit agencies and planning organizations are or will be exploring the potential of BRT. For those transit agencies that are planning BRT-like transit enhancements, a BRT modeling toolbox will be useful. A BRT modeling toolbox could have direct application to the FTA's efforts to demonstrate BRT systems. It addresses many of the essential features of BRT and can provide system-wide or location specific analyses. The particular transit-centric application of a BRT simulation model can provide a rapid modeling and sensitivity environment for the BRT project sites.

Also, analysis tools that assist transit agencies and their regions in determining the appropriate alternatives to meet a cooridor's mobility needs must also be modified or developed to properly reflect both BRT and integrated ITS within it. These include: sketch planning methods to help in generating and filtering initial options; Cooridor analyses tools for systems planning and alternatives analysis (regional network models), and operational simulations for assisting in operational design and implementation.

7.2.1 BRT Modeling Process

A modeling process developed specifically for BRT operations would equip planning professionals with a much needed tool to evaluate various BRT components. It would enable communities to test individual advanced bus strategies that are transitional steps to BRT as well as worthwhile enhancements on their own.

The two research projects undertaken thus far have provided a much needed foundation for developing a BRT modeling process. The Multisystems SBIR Project was a proof-of-concept research effort that proved the ability to model BRT systems using the VIISIM simulation program. They made a number of recommendations to improve the process that included incorporating methods to model ITS technologies. PATH's SmartBRT simulation tool utilizes the Paramics simulation program and has a 3-D visualization component as well. However, the Paramics program strength lies in its ability to model freeway while VIISIM models signalized corridors well, especially transit signal priority treatments at signalized intersections.

Building upon this research, an overall BRT modeling process should be developed that incorporates available simulation tools and modeling approaches into an overall BRT modeling process that communities can utilize to analyze and promote BRT systems. The process should provide a clear and succinct method by which planners can model a host of BRT features and ITS technologies using a range of currently available products that will enable planners to quantify the marginal benefits of ITS technologies.

7.2.2 Ongoing Monitoring of ITS Utilization at BRT Sites

The hierarchy of BRT-ITS technologies presented in the ITS Enhanced BRT White Paper is a first-step in defining the relationship between ITS and BRT. In order to further define this relationship it is important to continue to monitor and document the utilization of ITS technologies by BRT sites. This ongoing monitoring will provide the necessary data with which to update and verify the hierarchy of BRT-ITS technologies.

7.2.3 Performance Evaluation Guide

This research will focus on the introduction of appropriate BRT/ITS evaluation methods and tools, data collection techniques, potential performance measures, and consistent benefits/costs data reporting schemes for easy information sharing.
Referenced from FTA Transit ITS Program Plan Project 4.12, FY 05.

7.2.4 Cost-Benefit Analysis of ITS Technologies Application to BRT Stages

As more BRT sites deploy ITS technologies and evaluations of these systems are conducted, a cost-benefit analysis should be performed to quantify both the costs and impacts of ITS deployed in various BRT environments. This data will feed into the previous project, BRT Modeling Process.

7.3 Other Recommended Actions

7.3.1 Ongoing Transit ITS Projects

Parallel activities in evaluation and tool development that incorporate some aspect of BRT or otherwise related should be closely monitored and coordinated with as they move forward. These include:

- Handbook/Guidance on Incorporating Transit ITS Improvement into Current Planning Model Networks / Passenger Forecasting Methods (ITS Transit 10.15)
- IDAS and Transit ITS Case Study (ITS Transit 10.18)
- Transit ITS Impacts on Traveler Behavior Research (information, reliability, fare box convenience) (ITS Transit 10.25)

7.3.2 Sketch Planning and Parametric Analysis Techniques

Sketch planning and parametric analysis techniques that have been recently completed include the IDAS sketch planning tool, and the Transit Capacity and Quality Of Service Handbook. Both should be evaluated for their ability to discern the different stages of BRT and their incorporation of ITS components.

7.3.3 NGSIM

A related effort is the development of the Next Generation Simulation (NGSIM) tool for traffic analysis. While not specifically concerned with transit or BRT, it is imperative that the tools that result provide for the analysis of BRT systems as they interact with the overall transportation network. Therefore, FTA should make a special effort to monitor and provide inputs to this activity.

7.3.4 FTA New Starts Process and BRT

There are ongoing efforts to improve the ability of regional modeling tools used for alternatives analysis and FTA New Starts evaluations to properly reflect the benefits of BRT alternatives in their analyses. These efforts need to be examined to insure the inclusion of ITS-BRT elements.

8.0 BRT-ITS Outreach and Training

BRT is still a relatively new operational concept in public transportation and has demonstrated promising potentials in several cities worldwide, including a few in the US. In a time when people, especially those who live in major metropolitan areas, are becoming more and more concerned about and suffered from public finance constraints, clogged highways, and deteriorated environmental quality, BRT appears to be an attractive alternative to address people's mobility needs. ITS plays a key role in the operation of BRT systems. There are numerous ITS technologies involved in turning ordinary bus service into BRT. These ITS technologies collectively define BRT system characteristics and enable BRT to provide higher quality of service in terms of safety, speed, comfort, and convenience. Since it will take some time for this new concept to be integrated with the more traditional perspectives, it's important now to devote specific attention and guidance to bring people up to speed quickly on ITS technologies that are relevant to BRT.

Despite of the rapidly growing public awareness and community discussions about BRT-ITS in the United States, the extent to which ITS technologies are incorporated into the design of BRT has shown relatively modest growth. A summary of the twenty-one BRT sites, as shown in the ITS Enhanced BRT report Table 3.1, reveals that of the 21 BRT applicable ITS technologies, the number of technologies utilized increases from 5.5 among ten operational BRT sites to 6.3 among eleven planned, not yet operational, BRT sites. Although this slow growth in ITS usage in BRT operations may not necessarily indicate the deficiency of current outreach and training effort, it nevertheless provides a potential lead for further investigation.

8.1 Current Research and Products

- **BRT Workshops—**Following the kickoff workshop held in August 1999, the FTA Bus Rapid Transit project continues to sponsor BRT workshops for BRT Consortium members. These workshops provide an avenue for peers in the transit industry involved in BRT to meet and share ideas on common issues, learn from each other, avoid replicating mistakes, and explore new technology.
  Status: active
- **Bus Rapid Transit Reference Guide—**This is a FTA initiative that provides a concise introduction to key BRT concepts (e.g., reduce travel time by giving priority) and features (e.g., traffic signal priority and passenger information) through its web site at http://www.fta.dot.gov/brt/guide/index.html. This reference guide is intended to assist project planners and the public in becoming familiar with BRT concepts and strategies

that can be used to enhance the quality of service and promote public image of public transportation.
status: completed

- **ITS Enhanced Bus Rapid Transit—**This project can be logically defined as an extension of the previous product – the Reference Guide. It further explores the relationship between BRT and ITS technologies. The outcomes may be used as a planning tool to assist project participants in reaching a consensus on a set of ITS technologies that is most suitable for the local BRT operation configurations and environment characteristics.
Status: Draft Report (MTS, February 2003)
- **BRT Consortium and BRT Institute—**The Federal Transit Administration selected ten national demonstration sites for the FTA BRT Demonstration Program. The BRT Consortium was then organized by FTA to bring together demonstration site representatives, including planners and operations managers from transit agencies across the nation to discuss and exchange ideas, share common concerns and experiences relating to BRT issues and concept development. The BRT Institute, housed in the University of Southern Florida, is intended to supplement the FTA Demonstration Program by creating a central location for training, technical assistance, research, innovation, and evaluation of existing and proposed BRT projects, and to disseminate worldwide knowledge on BRT "lessons learned" through information sharing and research.
Status: active
- **TCRP Project A-23 Implementation Guidelines for Bus Rapid Transit Systems**
This TCRP initiative provides a comprehensive overview of the features, designs, and implementation of BRT projects. Products from this study include the following: (status: active)
    - A marketing information brochure "BRT – Why Communities Are Choosing Bus Rapid Transit" that describes the BRT concept and illustrates the range of applications and benefits of BRT to stakeholders, including citizens, transit operators, planners, traffic engineers, and public officials.
    - A report titled "Case Studies in Bus Rapid Transit" that describes the characteristics of BRT and identifies BRT related planning, designing and operational implications based on empirical evidence.
    - "Planning and Implementation Guidelines" that address many issues associated with BRT, including ITS technologies and deployment strategies.

  Status: Near Completion (May 2003)

8.2 Recommendations

The concept of BRT is relatively new in the United States. Preliminary evaluation results based on the limited BRT deployment experiences, such as Los Angeles Metro Rapid, have been released recently. As existing operational BRT systems start revealing their longer term impacts and other planned BRT sites enter into the deployment phase, more BRT related knowledge and lessons are expected in the foreseeable future through deployment evaluations and simulation modeling outcomes. USDOT should assume the leadership role to ensure that proper outreach instruments are used and adequate training opportunities are provided to transit operators and policy decision makers to broaden the understanding of BRT in general, BRT-ITS technologies in particular. The following initiatives are recommended to address the needs for BRT-ITS outreach and training. Some of the initiatives are new, while others should be incorporated into existing outreach and training effort.

8.2.1 BRT-ITS Technical Implementation Workshops

In order to further disseminate the results of this research and enable BRT sites to better plan for and utilize available ITS technologies, a series of BRT-ITS workshop should be held that discusses specific BRT-ITS technical issues. The workshops should be designed and delivered by experts in the field of transit-ITS, including FTA staff, as well as professionals who have recent hands-on BRT-ITS experience. This initiative should be incorporated as a part of the ongoing FTA BRT Workshops that have been held throughout the country.

8.2.2 BRT-ITS Planning Guide

Current BRT research paid limited attention to the integral role ITS can play in BRT systems. ITS has not been addressed in any significant way in much of the current BRT research including the earlier mentioned TCRP A-23 project, and the current FTA BRT Program Status report currently in development. A BRT-ITS Planning Guide should be developed that is geared towards local and state agencies interested in implementing a BRT system with greater degree of ITS involvement. The planning guide should focus on the benefits of ITS technologies to BRT systems, including case study examples where available and various scenarios of ITS-enhancements to BRT systems that will impact transit operations. It should also touch on National ITS Architecture Consistency Policy and related ITS Standards issues since BRT project that incorporates ITS technologies is most certainly a "Major ITS Projects" by definition.

8.2.3 BRT-ITS Operation Policies/Protocols

Due to its unique system configuration and service characteristics, BRT may require separate operating protocols and polices, such as dispatcher's incident response procedures, that are different to traditional bus fleet operational strategies. It is advised to conduct an overhaul of existing general protocols and policies (or common industry practice) used by transit agencies for traditional bus operations and determine the needs for modifications, if any, to address unique operational scenarios resulting from the introduction and integration of BRT systems. Control center dispatchers and field supervisors should also obtain adequate trainings concerning proper response to different service scenarios. This is especially important because BRT is often operated by transit agencies that also managed bus operations. This effort should be guided by experts with hands-on BRT operational experiences.

8.2.4 International Experiences with BRT with Comprehensive Coverage

So far BRT deployment in the United States remains limited in scope on a corridor by corridor basis. There may be some additional BRT operational issues, such as assigning traffic signal priority to crossing BRT corridors, that are likely to emerge only when the system is expanded for greater service coverage with more routes and shorter headways. Some international BRT-ITS deployment experiences, such as the Brisbane, Australia South East Busway System, may provide valuable knowledge on operational issues unique to larger scale BRT/ITS deployment. It is advised to expand the scope of the proposed Transit ITS Program Plan Project 4.10 – Explore International Perspective of BRT Implementation to not only monitor international BRT activities (i.e., the original scope), but also capture lessons learned from larger-scale international BRT-ITS deployment so that proper proactive measures may be taken during the planning stage and design stages before the actual expansion of current BRT-ITS systems in the United States.
Referenced from FTA Transit ITS Program Plan Project 4.10, FY 2004.

8.3 Other Recommended Actions

8.3.1 BRT-ITS Training

The FTA should review existing BRT training courses and transit planning courses to insure inclusion of BRT-ITS concepts. If needed, separate training modules should be developed.
Referenced from FTA Transit ITS Program Plan Project 12.01b, FY 2003.