ITS Enhanced Bus Rapid Transit Systems

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Summary: BRT will combine Intelligent Transportation System (ITS) technology with modern land use planning and transportation policies to support new concepts for rapid transit systems based on bus-like vehicles. This research will explore the relationship between BRT and ITS technologies in order to determine the best set of ITS enhancements to optimize overall BRT performance. This research attempts to articulate appropriate sets of ITS technologies for various BRT operational configurations and presents a proposed Hierarchy of ITS Technologies for BRT systems.

INTRODUCTION

Communities have been looking for new and innovative approaches to address increasing urban congestion and associated pollution while providing efficient and effective transportation options. Adding more highways is expensive and disruptive, and is not always an environmentally sound approach. However, light rail rapid transit systems, of interest to many communities, require a significant initial capital investment, and may not be an effective solution for all urban transportation problems. Transit buses provide an essential transportation service in metropolitan areas, but are often viewed as slow and unreliable.

One innovative approach is the use of buses rather than light and / or heavy rail, in an integrated, well defined system with design features similar to light rail rapid transit systems. Some of the features of these Bus Rapid Transit (BRT) Systems that may be similar to light rail rapid transit systems include:

- Dedicated right-of-way
- Limited stops with fast travel between stops
- Rapid loading and unloading of vehicles on platforms and using multiple entryways
- Simplified, fast fare collection
- Communications and safety systems

BRT will utilize Intelligent Transportation System (ITS) technology, modern land use planning and transportation policies to support new concepts for rapid transit systems based on bus-like vehicles. The success of some of these pioneering systems, such as the systems in Curitiba and San Paolo, Brazil, have shown that these systems are capable of providing heavily-used, high capacity rapid transit at a reduced cost.

In order to better understand BRT and ITS the FTA conducted a research effort to explore this area. The research effort was prepared to explore the relationship between BRT and ITS technologies in order to determine the best set of ITS enhancements to optimize overall BRT performance. The final report, published in June 2003, articulates appropriate sets of ITS technologies for various BRT operational configurations. This paper is summary of that research effort.

BRT OVERVIEW

BRT is designed to address the sources of delay of traditional bus service and to be an attractive service to passengers. BRT is an incrementally enhanced transit mode, providing faster, passenger-friendly service. This is accomplished in multiple ways including improvement to the infrastructure, vehicle road use and stops/stations; utilizing cleaner, quieter and lighter vehicles; and integrating an amalgam of ITS technologies.

The goals for a BRT system are similar to the goals of other rapid transit systems. The service must be rapid, providing reduced travel times to passengers. However, there are other BRT service goals that can provide a meaningful rapid transit service. The following is a generally agreed upon list of BRT goals:

- **Shorter trip times**—Fewer stops; Faster travel; Less congestion
- **Short wait**—More frequent service; Even spacing between vehicles
- **Easy to use**—Easy and rapid embarkation and debarkation; Simple fare collection; Clear signing including indication of routing
- **Accessible**—Ease of access for physically challenged and elderly
- **Welcoming**—Comfortable vehicle interior designed for both seating and standing; Clean, affordable service (in line with other transit services)
- **Integrated**—Convenient to parking and other transportation modes including neighborhood bus service and bicycle access
- **Distinctive**—Modern, distinctive design for vehicles and stations
- **Low environmental impact**—Low-emission and low-noise transit vehicles
- **Incremental development**—Service can grow to meet rising demand and to accommodate new technologies

The Federal Transit Administration has defined four stages of BRT Deployment. The following table summarizes the stages of BRT service. The table provides typical combinations of 1) Right-Of-Way Use, 2) Level of Management, 3) Vehicles, and 4) Stations. There are four different deployment stages of BRT systems, although some systems have linked together more than one of the deployment stages. The distinctions are largely based on the use of the roadway and supporting infrastructure that affects BRT operation. The stages of BRT systems are:

BRT Stage	Supporting Infrastructure	Example
I	▪ Mixed Traffic on Corridors and Streets ▪ Moderate Operations Management Improvements ▪ Some Vehicle Improvements ▪ Improved Stops	Los Angeles, CA
II	▪ Mixed Traffic on Expressway ▪ Significant Operations Management Improvements ▪ Some Vehicle Improvements for Ease of Use ▪ Upgraded Stations and / or Stops	Minneapolis, MN
III	▪ Semi-Dedicated Lanes ▪ Significant Operations Management Improvements ▪ Some Vehicle Improvements for Ease of Use ▪ Upgraded Stations and Stops	Miami, FL
IV	▪ Dedicated Lanes ▪ Extensive Operations Management Improvements ▪ Vehicles Designed for Ease of Access and Comfort (multiple doors, interior configuration) ▪ Advanced Station Design	Dulles Corridor, VA

INTEGRATION OF ITS AND BRT

There are many technologies and operational features that can be utilized when designing BRT systems. Some have been applied to standard bus systems to help make them more efficient. A BRT system typically is a combination of technologies, features, and land use that together make it effective and efficient.

Currently, there are twenty-one (21) ITS technologies, which can be integrated into BRT systems, that have been defined. Other technologies will emerge over time. For the purpose of this paper, the technologies have been categorized in the following six groups in order to organize future recommendations and actions:

- **Vehicle Prioritization**—This technology group includes methods to provide preference or priority to the BRT vehicles. Signal Timing / Phasing and Signal Priority help BRT vehicles minimize delay caused by having to stop for traffic at intersections. Access Control provides the BRT vehicles with unencumbered entrance to and exit from their facilities. All prioritization for BRT vehicles reduces travel delay and increases reliability of the BRT operation.

- **IVI Technology**—This technology group includes Intelligent Vehicle Initiatives which provide automated controls for a BRT vehicle. Use of the Collision Warning function assists a driver to operate a BRT vehicle safely. Use of Collision Avoidance, Lane Assist, and Precision Docking functions provides for direct control of the BRT vehicle when making avoidance, guidance or docking maneuvers. All IVI functions help to reduce frequency and severity of crashes and collisions and provide reduced travel or boarding times.

- **Fare Collection—**This technology group includes some method of electronic fare collection which provides a fast, cashless interface for the passenger. Use of magnetic stripe and smart card technologies are proven and the benefits of electronic payment systems are known. Use of either station-based or vehicle-based fare collection helps to reduced dwell times and increase passenger convenience.

- **Operations Management**—This technology group includes automation methods which provide for enhanced operations management for a BRT fleet. Use of an Advanced Communication System can be the backbone to support various functions of fleet operational management. Use of Automated Scheduling Dispatch System and a Vehicle Tracking method assists BRT management to best utilize the BRT vehicles. Use of Vehicle Mechanical Monitoring and Maintenance assists in minimizing downtime of the BRT vehicles. All Operations Management functions improve operating efficiencies which supports a reliable service and reduced travel times.

- **Passenger Information**—This technology group includes various methods of providing information to passengers so they can make the best use of their time. Information about the vehicle schedule can be provided at the station / stop and / or on the vehicle. Providing schedule information to travelers via PDA, cell phone or similar device and supporting trip planning are other functions that can be provided, if there is sufficient need by travelers. All the Passenger Information functions improve passenger satisfaction, help to reduced wait times, and can increase ridership.

- **Other Technology**—This technology group includes functions which provide some unique enhancements for a BRT system. Use of Archived Data and automatic Passenger Counters can support operations and planning efforts for operating a BRT fleet. Use of Silent Alarms and Monitoring systems can increase the security of the operation. All of these functions can help to support passenger satisfaction.

The ITS technologies that are used in, or planned for, each of the twenty-one BRT sites are shown in **Table 1: BRT Sites: ITS Technologies**. Each of the twenty-one site's information is provided in columns, which are shown alphabetically. All of the BRT sites are planning to implement some amount of ITS technologies. The number of ITS technologies to be utilized ranges between 2 (Louisville, KY) and 14 (Dulles Corridor, VA) with an average of 5.9. Generally, a majority of the BRT sites will utilize between 3 and 8 ITS technologies.

Within the ITS technologies themselves, the most popular group of ITS technologies are Vehicle Prioritization (20 BRT sites), Operations Management (18) and Fare Collection (17). The most popular individual ITS technologies include Vehicle Tracking and Traveler Information at Station/Stop (18 each), Transit Signal Priority (17) and Vehicle-based Electronic Fare Payment (11). The least popular ITS technologies are Station and Lane Access Control, Traveler Information of Person, Archived Data (0 each), Collision Avoidance, Vehicle Mechanical Monitoring and Maintenance (1 each) and Signal Timing/Phasing and Silent Alarms (3 each).

TECHNOLOGY BENEFITS

ITS technologies have been proven to help transit agencies increase safety and operational efficiencies. Remote monitoring of transit vehicle status and passenger activity helps to provide additional safety and security to passengers. ITS technologies also assist operations in maintaining vehicle fleets. Vehicle self-diagnostics can alert mechanics of impending mechanical problems as well as routine maintenance needs. AVL that utilizes Automated Scheduling and Dispatch Service (ASDS) can improve scheduling activities and schedule adherence. All of these technologies have demonstrated that they are capable of reducing travel time both by improving the operation of the vehicle and the overall operation of the transportation network.

BRT is designed to overcome weaknesses of traditional service and sources of delay. Individual ITS technologies provide the basic features key to many of BRT's benefits. Combinations of ITS technologies can work together to provide synergies to increase improvements in service. Separately, all of these ITS technologies would provide no unique benefit to BRT systems. Collectively they help to define BRT. What makes BRT unique is that it requires a combination, or set, of technologies to help meet system requirements. A transit bus system that does not include AVL or EFP is still a transit bus system. However, a BRT system that does not include AVL or EFP is only a transit bus system. Therefore, it is important to articulate those ITS technologies, either requisite or optional, that provide some amount of benefit to: 1) further define BRT system characteristics, 2) meet BRT goals, and 3) contribute to BRT user benefits. The following three sections examine each of these areas in detail.

HIERARCHY OF BRT-ITS TECHNOLOGIES

There is a correlation between the four BRT operational configuration stages and performance, as measured by speed of operation. Generally speaking, BRT system performance will be defined more by the infrastructure on which it operates than by any other factor. For example, a BRT system which has a dedicated lane that is separated by physical barriers from other traffic and incorporates grade-separated interchanges (Stage IV) will have greater performance than a BRT system that operates within mixed traffic on a local street (Stage I). Even with a high utilization of ITS technologies, the BRT system operating in mixed traffic can never meet the performance capability of a BRT system with dedicated lanes. Regardless of ITS utilizations, the BRT system performance is higher for each stage from I through IV.

Figure 1: Hierarchy of BRT-ITS Technology shows the interaction of BRT system performance (horizontal axis) and the deployment of ITS technologies (vertical axis). The width of each rectangular box indicates the potential range of system performance each BRT stage can achieve. For example, each BRT stage has a potential range of system performance that will depend on many factors. These factors may include the operating environment, vehicle preference, local traffic conditions, etc. These stages are meant to indicate relative system performance between stages, and not as absolute measures.

The placement of the four boxes shows the relative position of the four BRT stages with respect to Deployment and Performance. For example, regardless of technology deployment, a Stage IV BRT system will have high system performance while a Stage I BRT system will have a lower system performance. Stage II and III systems overlap indicating that in some instances a Stage II system may in fact have better system performance than a Stage III. The same is true about Stage I and Stage II systems. However, a Stage IV system will always operate at higher system performance than a Stage III.

To some degree, the performance of the BRT system can be impacted by the utilization of ITS technologies. Therefore, the height of the rectangular box shows the potential impact technology can have on BRT system performance and the amount of technology one might expect within a given service stage of BRT. For example, a Stage I BRT system operating on local streets may not include a lot of technologies; however, there are certain technologies, such as transit signal priority, that may significantly improve system performance. Therefore, a given BRT level may start at a certain system performance point and have some number of ITS elements, but as more ITS technologies are added, the system performance will increase.

Of course, quantifying the impact of the ITS technologies against system performance is an ongoing task. However, generalizations about the potential impact of the twenty-one BRT-related ITS technologies can be made. Figure 1 also graphically shows the rank of each of the twenty-one ITS technologies and the impact each has on BRT system performance. It indicates the stage at which each technology will most likely appear. The vertical placement, or rank, of the twenty-one ITS technologies as horizontal bands on the graph was determined by the following criteria:

- Ability to further define BRT system characteristics
- Impact the technology has on meeting BRT goals
- Amount of user benefits

Other criteria that were used, to a lesser extent, include market penetration within current and planned BRT operations, its overall importance to the operation of other ITS technologies, and its difficulty to implement.

For example, an advanced communication system:

- Helps to define nine BRT system characteristics
- Impacts five of the BRT goals
- Provides primary benefits to the BRT operator and secondary benefit to the driver and traveler

In addition, it has a rather high market penetration; it is an important enabler to many other ITS technologies and it is relatively easy to implement.

On the other hand, Traveler Information on Vehicle:

- Helps to define one BRT system characteristic
- Impacts four of the BRT goals
- Provides primary benefits to only the BRT traveler

Also, it does not have a high market penetration, has little importance to the operation of other ITS technologies, and is rather difficult to implement. Hence, an advanced communication system is lower on the Deployment of Technology axis (meaning it is more important) and the traveler information is higher on the axis (meaning it is less important). The length on the horizontal band has significance as well. Some of the bands (Transit Signal Priority) do not cross over to the Stage IV BRT system since it is unlikely that a Stage IV system would need TSP if it is operating within its own R.O.W. and does not interact with other traffic.

In addition to the rank of the twenty-one ITS technologies, they also were grouped by their difficulty to deploy: low, medium and high. This provides a more generalized picture of those technologies or group of technologies that are important, since arguments can be made for or against the specific rank of the technologies. There are five low, nine medium, and seven high technologies. The Hierarchy of BRT-ITS Technologies provides a much needed framework for the prioritization of ITS technologies within BRT systems.

UTILIZATION OF ITS TECHNOLOGIES IN EXISTING BRT SYSTEMS

There are currently 10 operational BRT sites in the United States. As shown in Table 1, the ten BRT sites include at least one each of the four BRT stages. Most sites started their BRT operations utilizing a few of the ITS technologies that they desire to implement. Vehicle Tracking is the most popular technology with nine existing sites including it in their plans.

Boston, Charlotte, Chicago, Los Angeles, Miami, Minneapolis, Orlando, and Pittsburgh are using this technology; Santa Clara will implement it as part of a future phase. Transit Signal Priority is the next most popular technology with eight existing sites including it in their plans. Los Angeles and Santa Clara are the most notable implementations of this technology. Traveler Information at Stations / Stops is also a popular technology with eight sites utilizing it. Los Angeles and Orlando are the most notable implementations of this technology. For both of these technologies, a number of the existing sites are planning their implementation of these two technologies as part of a future phase. Electronic Fare Payment is also included in the plans of eight sites. However none have implemented the technology.

In addition to the specific technologies noted above, technologies from three of the technology groups, Operations Management, IVI Technology, and Other Technology, are included in the plans of a number of existing sites. Some of the existing sites are using or are planning to use Operations Management technologies; including Advanced Communication Systems (Boston, Orlando, and Santa Clara), and Automated Scheduling Dispatch Systems (Boston, Charlotte, and Miami). Others are using or are planning to use IVI Technologies; including Collision Warning (Minneapolis, Orlando, and Pittsburgh), Lane Assist (Minneapolis and Orlando), and Precision Docking (Minneapolis and Orlando). In addition, others are planning to use Other Technologies; including Passenger Counters (Charlotte and Los Angeles), Voice and Video Monitoring (Boston and Charlotte), and Silent Alarms (Boston).

It is apparent that all of the BRT sites have thought about deploying ITS technologies as part of their BRT system. From this analysis, the most favored ITS technologies include Vehicle Tracking (9 sites), Transit Signal Priority (8 sites), Vehicle-based Electronic Fare Payment (8 sites) and Traveler Information at Station/Stop (8 sites). In reality, only a few of the BRT sites have deployed the ITS technologies. For example, none of the sites have deployed Electronic Fare Payment. Only two of the sites have a Traveler Information System while eight have said they want to deploy such a system.

Regardless of what ITS technologies have been deployed, in order for all of these technologies to function properly, and for the future utilization of additional ITS technologies, it is imperative that there is an underlying communication system that is robust enough to support the communication needs of the technology. However, only three of the sites have planned for an advanced communication system that will be able to handle the significant increase in data bandwidth required for the ITS technologies.

CONCLUSIONS

Among the twenty-one BRT sites, most are either currently using or are planning to use ITS technologies. In fact, the twenty-one BRT sites used an average of 5.9 ITS technologies each, with a range from 2 to 14. But the average was 8 for Stage IV, 5.8 or 6 for Stages II and III, and 4.8 for Stage I. However, there are some core technologies that many of the BRT sites are missing. First is an Advanced Communication System. Only eight sites have indicated their use of an Advanced Communication System. An Advanced Communication System is necessary in order for the full potential of an integrated set of ITS technologies to be realized. Second is an Electronic Fare Collection system and the implications it will have on system operations. Almost all of the BRT sites indicate they will utilize Electronic Fare Collection, but none of the operational systems currently have it in operation. Electronic Fare Collection has the potential to significantly reduce boarding time and provide benefits to travelers, drivers and operations. Third is Vehicle Prioritization for the Stage I, II and III BRT sites. Since these three BRT stages must interact with other traffic and traffic signals, Vehicle Prioritization has the potential to provide significant travel time savings. Finally are the IVI technologies. Currently, significant amounts of time and money are being spent on researching and developing IVI technologies for transit buses. BRT vehicles are an ideal platform on which to deploy IVI technologies and many of the BRT sites could benefit from them.

Overall, ITS technologies have the potential to provide a greater increase in BRT system performance. It is clear that ITS is needed for a BRT system regardless if it operates on city streets or its own dedicated R.O.W. The key to BRT and ITS is to focus upon the marginal benefit that one technology may provide to a certain BRT system. A Stage IV BRT system has nearly maximized BRT system performance by operating on a dedicated R.O.W. The marginal benefit it may gain from incorporating Precision Docking technology will be less than the marginal benefit gained by a Stage I BRT system operating on city streets that decides to deploy Transit Signal Priority.

Some level of ITS technologies is beneficial in the operation of a BRT system. However, ITS technology does not necessarily define BRT. First and foremost, BRT systems are defined by their operating environment. In this report the BRT operating environments have been categorized into four separate stages. Within each stage, there is an expected utilization of ITS technologies. Many of the technologies span more than one BRT stage. However, there is no defined set of ITS technologies that is required in order for a bus transit system to become a BRT system. Rather, BRT relies on the synergistic effect of a collection of ITS technologies to provide significant user benefits that creates a new type of transit system.

Table 1 BRT Sites: ITS Technologies

ITS Technology	Alameda Contra Costa, CA	Albany, NY	Boston, MA	Charlotte, NC	Chicago, IL	Cleveland, OH	Dulles Corridor, VA	Eugene, OR	Hartford, CT	Honolulu, HI	Las Vegas, NV	Los Angeles, CA	Louisville, KY	Miami, FL	Minneapolis, MN	Montgomery County, MD	Orlando, FL	Pheonix, AZ	Pittdburgh, PA	San Juan, PR	Santa Clara, CA	Sum
Start [Bold indicates operational]	Jul-03	2006	**Jul-02**	**Dec-98**	**2000**	late 2006	2003	mid 2004	Jan-06	**Mar-99**	Nov-03	**Jun-00**	2007	**Feb-97**	**late 1990s**	2006	**1997**	2003	**Dec-77**	late 2003	**late 2001**	
Vehicle Prioritization																						
Signal Timing / Phasing													X			X			X			**3**
Station and Lane Access Control																						**0**
Transit Signal Priority	X	X	X		X	X	X	X	X	X	X	X		X	X		X	X		X	X	**17**
IVI Technology																						
Collision Avoidance							X															**1**
Collision Warning							X								X		X		X			**4**
Lane Assist							X	X							X		X					**4**
Precision Docking Technology							X	X			X				X		X					**5**
Fare Collection																						
Station-based Electronic Fare Payment							X	X	X				X					X		X		**6**
Vehicle-based Electronic Fare Payment	X	X	X	X	X	X				X		X			X				X		X	**11**
Operations Management																						
Advanced Communication System		X	X			X	X				X						X	X			X	**8**
Automated Scheduling Dispatch System		X	X	X			X				X			X		X				X		**8**
Vehicle Mechanical Monitoring and Maintenance			X																			**1**
Vehicle Tracking		X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	**18**
Passenger Information																						
Traveler Information at Station/Stop	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	**18**
Traveler Information on Person																						**0**
Traveler Information on Vehicle		X	X	X		X	X	X	X									X				**8**
Trip Itinerary Planning							X															**1**
Other Technology																						
Archived Data																						**0**
Passenger Counter		X		X		X						X										**4**
Silent Alarms			X			X	X															**3**
Voice and Video Monitoring			X	X			X													X		**4**
Sum	**3**	**8**	**10**	**7**	**4**	**8**	**14**	**7**	**5**	**3**	**6**	**5**	**2**	**3**	**6**	**4**	**7**	**6**	**5**	**6**	**5**	

Figure 1 Hierarchy of BRT-ITS Technologies