Overview of Bus Rapid Transit Opportunities as Part of an Integrated Multi-Modal Strategy to Alleviate Traffic Congestion in Miami-Dade County

Technical Memorandum Two (2): Literature Review & Recommended Bus Rapid Transit Elements

Prepared for:

Miami-Dade Metropolitan Planning Organization

Prepared by:

Center for Urban Transportation Research
National Bus Rapid Transit Institute
College of Engineering, University of South Florida
4202 E. Fowler Avenue CUT 100
Tampa, Florida 33620-5375

February 2005 – Final

This page intentionally left blank.

Table of Contents

1. Introduction 1

2. Definition of Bus Rapid Transit 1

3. Literature Review: Bus Rapid Transit Elements 2

3.1 Runningway Types 4
3.1.1 Dedicated Right-of-Way 4
3.1.2 Buses in HOV Lanes 6
3.1.3 Designated (Reserved) Arterial Bus-Only Lanes 6
3.1.4 Mixed Traffic Lanes 9
3.1.5 Planning and Implementation Issues 10

3.2 Stations 11
3.2.1 Station Considerations 11
3.2.2 Station Type 12
3.2.3 Station Location 13
3.2.4 Platform Height 14
3.2.5 Passing Capability 16
3.2.6 Station Access 17
3.2.7 Station Operational Issues 19
3.2.8 Station Implementation Issues 20

3.3 Intelligent Transportation Systems (ITS) 23
3.3.1 Characteristics of ITS 24
3.3.2 Transit Signal Priority 24
3.3.3 Assist & Automation Technology (AAT) 25
3.3.4 Electronic Fare Collection 27
3.3.5 Passenger Information 27
3.3.6 Safety & Security 27

3.4 Vehicle Design 28
3.4.1 Low-Floor Design 28
3.4.2 Door Capacity 29
3.4.3 On-Board Amenities 29
3.4.4 Propulsion System 29
3.4.5 Design & Appearance 30

3.5 Fare Collection 32

3.6 Operation and Service Planning 33
3.6.1 Characteristics of Operation & Service Planning 33
3.6.2 Route Length 34
3.6.3 Route Structure 34
3.6.4 Service Span 35
3.6.5 Service Frequency 35
3.6.6 Station Spacing 35
3.6.7 Schedule-Based Control 36
3.6.8 Headway-Based Control 36
3.6.9 All Day Span of Service 36
3.6.10 Peak Hour Only Span of Service 37
3.6.11 Single Route Structure 37
3.6.12 Overlapping Route with Skip Stop or Express Variations 37
3.6.13 Integrated or Network System 37

4. Recommendations for Miami-Dade County (MDC) **38**

4.1 Elements Recommended for all MDC BRT Corridors *39*

4.1.1 Runningways 39
4.1.2 Stations 41
4.1.3 Vehicles 42
4.1.4 Intelligent Transportation Systems and Fare Collection 43
4.1.5 Operation and Service Plan 45
4.1.6 Distinctive System Branding & Marketing 46

5. Next Steps **46**

Appendix A – Technical Memorandum One (1) **51**

Appendix B – List of Transit Terminology **67**

Appendix C – References **85**

List of Exhibits

EXHIBIT 1: Examples of Service Options and BRT Route Capacity 43

EXHIBIT 2: Major BRT Elements – System Performance - System Benefits 48

This page intentionally left blank.

1. Introduction

Technical Memorandum Two (2) summarizes work conducted in accordance with Subtask B "Development of Alternative BRT System Configurations" of Task III in the study scope of work. Technical Memorandum One (1) includes the detailed selection of 11 potential Bus Rapid Transit (BRT) corridors in Miami-Dade County (MDC). A copy of the final version of Technical Memorandum One (1) is included in Appendix A for reference. It was completed in accordance with Task II of the study scope of work.

In accordance with Subtask B of the study scope of work, this tech memo summarizes the conceptual design of the 11 proposed BRT corridors by identifying what major BRT elements should be included in the overall MDC BRT program. An iterative and firsthand knowledge of MDC was used to determine the potential route alignments and which major BRT system elements best suit each corridor. In order to maintain or otherwise improve service by maintaining high average travel speeds consistent with rapid transit service, BRT examples in other cities indicate that the route alignment should be as linear in nature as possible with few, if any vehicle turning. This fact was a strong consideration in developing the BRT route alignments and the corresponding major BRT elements selected to compliment the routing in each corridor. In addition, when selecting route alignments and major BRT system elements strong consideration was given to potential inter-modal and transfer locations to increase the connectivity of the countywide network of transit services.

2. Definition of Bus Rapid Transit

Transit Cooperative Research Project (TCRP) *Report 90* defines BRT as "a flexible, rubber tired rapid transit mode that combines stations, vehicles, services, runningways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and they can be incrementally implemented in a variety of environments." Using a combination of technologies, unique design features, operating procedures, and marketing techniques BRT permits rubber-tired transit vehicles to approach the speed and service quality of rail-based rapid-transit modes. When considering BRT, decision-makers need to think “rail” but implement “bus” instead. Similar to rail, BRT systems are designed to decrease overall travel time, improve schedule reliability, and provide customers with a premium level of service beyond that of traditional/standard local service. In most cases, BRT emulates rail-based service but at a lower capital and operating cost than that of a new rail line, but not always. One central method for putting the “rapid” into BRT involves providing priority to arterial, mixed-traffic running BRT vehicles at all or selected signalized intersections along a route alignment while minimizing the impact on cross-street vehicular traffic. Giving priority to transit vehicles involves Transit Signal Priority (TSP) at signalized intersections. This is usually accomplished via holding a green light for seconds longer, giving an early green signal to an approaching BRT vehicle (i.e., shortening the red), or allowing BRT vehicles to proceed as the first vehicle of any type through the intersection using a special signal phase and a queue jumper lane. One other way of putting the “rapid” in BRT is to reduce dwell time or the amount of time BRT vehicles spend boarding and alighting customers at stations and stops. Studies indicate that transit vehicles spend in the neighborhood of 25 percent of total run time sitting idle at stations to board and deboard customers. The use of off-board fare payment (customers validating/paying before boarding the BRT vehicle) significantly reduces dwell time at stations due to elimination of customer queuing and interaction with the operator at the vehicle front door.

3. Literature Review: Bus Rapid Transit Elements

This tech memo provides a detailed review of the various elements used in BRT systems around the world. In the literature review, whenever possible, special emphasis is placed on BRT systems currently operating and located in contexts similar to the MDC operating environment. Utilizing literature and firsthand experience with BRT systems worldwide, this tech memo make recommendations about the elements of successful BRT systems that MDC should consider including in its countywide BRT program. In addition, images from BRT systems from around the world are provided to further illustrate each BRT element.

BRT consists of a combination of various technologies, design features, operating parameters, and marketing to offer premium bus-based transit service with the speed, reliability, comfort, and safety commonly associated with rail-based transit service. Common, but not exclusively, BRT system elements include dedicated guideways/runningways; limited stops (wide stop spacing); enhanced stations; ITS including TSP, real-time customer info, automated guidance, advanced off-board fare payment, and AVL; sleek rail-like vehicle designs; and improved access and egress to transit facilities. However, not all BRT systems employ all of these elements all of the time. Many systems around the world include a common-sense combination of these elements ranging from limited-stop bus routes with standard customer shelters, on-board fare payment, and traditional-styled vehicles operating curbside in mixed traffic like the Metro Rapid in Los Angeles to high capacity rail-like BRT service using sleek-styled articulated and guided vehicles that operate in designated bus-only runningway while serving stations with level platform boarding and proof-of-payment (POP) fare system similar to the TEOR BRT in Rouen, France.

The literature points out that the following are the major elements typically found in BRT systems:

- Runningway
- Stations
- Vehicles
- Fare collection
- Intelligent Transportation Systems
- Operation and service plan

The following sections discuss the major BRT elements and the different sub-elements within each.

3.1 Runningway Types

BRT systems operate in a range of environments from separation from vehicular traffic to complete isolation in busways to operating in mixed traffic on arterial streets. Similar to rail transit, increased separation from vehicular traffic will result in greater operating speeds, schedule reliability, and customer comfort; especially in areas with heavy traffic congestion. However, this also means that the BRT system may require a larger physical roadway cross-section to accommodate all users and usually involves inherently higher build and maintenance/operating costs.

BRT systems can operate on a combination of roadway types such as dedicated busways, HOV lanes on expressways, and mixed traffic lanes on arterials. As a result, BRT systems can be constructed incrementally, one segment at a time as funding permits. As traffic separation increases through a series of incremental improvements, the quality of service (decrease in overall travel time, reduced transferring, etc.) offered by the BRT system will increase over time.

The starting point for planning BRT is determining the corridor where BRT services will operate. The corridor defines what communities and locations a BRT facility serves. Once the corridor is defined, the BRT alignment and the physical runningways upon which the vehicles operate can be determined. Most often, the existing roadway network, especially arterial roads, form the foundation for BRT runningway such as the Metro Rapid in Los Angeles. Where higher levels of service and performance are desired, roadway space is typically reallocated or new construction within a highway or separate right-of-way is pursued. The following sections discuss the range of levels of segregation of BRT vehicles from regular traffic used in various BRT systems.

3.1.1 Dedicated Right-of-Way

The most isolated busways are fully grade-separated facilities on which only BRT vehicles (and most often emergency and government service vehicles such as fire and police) are permitted to travel. Overpasses or underpasses at intersections with other roads eliminate conflict with regular vehicular traffic. By running high-capacity transit vehicles at short headways, this type of runningway can achieve customer capacities per hour equal to or greater than that of many light and even heavy customer rail (subway) transit systems. For example, the TransMilineo BRT system operating in Bogotá, Colombia currently carries about one million trips per day over its approximate 25-mile one-way route. A fully grade-separated BRT runningway represents the highest level of separation and the highest level of cost but also the highest level of service.

During the 1970s, a number of transit malls using dedicated rights-of-way for vehicles were implemented in several downtown areas in the US. Locations included State Street in Chicago, the Transit Mall in Portland, Oregon, and the Nicollet Mall in Minneapolis. Each of these involved dedicating one or more streets to transit vehicle use only. In Downtown Seattle, a dedicated transit tunnel was constructed under 2nd Street to minimize interference with surface traffic. At present, this facility operates with dual-mode vehicles that convert from internal combustion to electric trolleybus operation at the transition to the tunnel. Another example of a transit mall based BRT system is the 16^{th} Street Mall in Downtown Denver. Downtown Denver is the hub of the regional bus network with more than 65 vehicle trips per hour during peak hours traveling in and out of Market Street and Civic Center Stations. These transit stations are anchored by the 16th Street Mall BRT system which stretches one mile through the heart of the Downtown. Serviced by a fleet of shuttles with 75-second intervals during peak hours, the Transit Mall vehicles currently carry about 65,000 customers daily.

Restriction on traffic to authorized transit vehicles can also allow exclusive BRT runningway to be designed with a narrower cross section than a standard traffic lane if automatic (lateral) or mechanical guidance mechanisms are used. Some dedicated BRT right-of-way has curbs on both sides of the lane against which small wheels on the vehicle mate to the concrete curb to laterally "guide" the vehicles. Using this design, lane width can be reduced to a narrow 9 feet or less from the standard 11 or 12 feet. The O-Bahn in Adelaide, Australia, and the SuperBus in Leeds, England are two of the most prominent examples of laterally-guided BRT systems currently in operation.

Dedicated Right-of-Way, Leeds, England

Source: www.nbrti.org

3.1.2 Buses in HOV Lanes

Express bus operations in mixed traffic on expressways and tollways were one of the first applications of BRT implemented in the United States. As with most express bus services, these BRT systems served the suburb to central business district (CBD) market. A very successful BRT HOV system is operated by the Metropolitan Transit Authority or Metro in Houston, Texas. Today, the Metro's six HOV corridors have over 112 miles of barrier-separated HOV lanes in use and a minor extension is being planned to increase the total number of miles to 115. Most of the park-n-ride lots are connected directly to the HOV barrier-separated lanes via strategically placed access ramps. Physically located in the center of six of Houston's eight major freeways, these HOV lanes typically are barrier-separated roadways that allow buses, vanpools, and carpools to move higher volumes of customers to and from Downtown and locations in between.

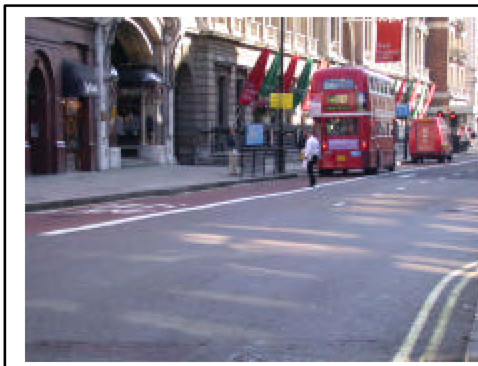
3.1.3 Designated (Reserved) Arterial Bus-Only Lanes

In corridors where the alignment of the BRT route follows an existing arterial roadway, designated bus-only lanes can provide BRT vehicles with a fast, reliable alternative to mixed flow traffic lanes. With a designated arterial lane, a traffic lane within an arterial roadway is set aside for the operation of BRT vehicles. Other vehicles can be restricted from using the lane at certain time such a peak periods in the peak direction. Also, this treatment should be enforced through a physical barrier, signage, and/or through police monitoring. As a result, BRT vehicles face minimal congestion delay between intersections. With designated lanes, BRT vehicles are not delayed in the approach to a station by a queue of other vehicles. Designated lanes thus reduce travel times and improve reliability.

Designated bus lanes are essentially regular traffic lanes converted into lanes for bus only use. The amount of street width needed to accommodate bus lanes, stations, barriers, through traffic, turning traffic, and parking varies by installation. As mentioned, designated arterial bus-only lanes can be in effect only during the peak hours in the peak direction; usually in conjunction with restricted on-street vehicle parking so that the bus lane is free from obstructions. At other non-peak times, exclusive bus lanes may serve as general-purpose travel lanes or as parking lanes in conjunction with BRT operation.

3.1.3.1 Curbside Lanes

Curbside designated bus-only lanes typically require the least modification to existing streets during implementation. They conserve width by allowing stations to be located off street on or near the sidewalk. Frequently, curbside lanes are shared with right-turning vehicles. However, curbside lanes are also the most difficult lanes to keep free of obstacles such as parked and standing and right-turning vehicles yielding to pedestrians. As a result, they tend to provide more restricted flow than designated median or contra-flow lanes, for example. It is possible to lessen or eliminate these effects by placing restrictions on right turns, enforce parking during certain hours such as peak hours, providing a passing lane for buses to pass one another, or constructing right-turn lanes between the bus-only lane and the curb. Transport for London (TfL) utilizes over 1,000 km of curbside bus-only lanes in and around Downtown London.



Curbside Bus-Only Lane, London, England
Source: www.nbrti.org

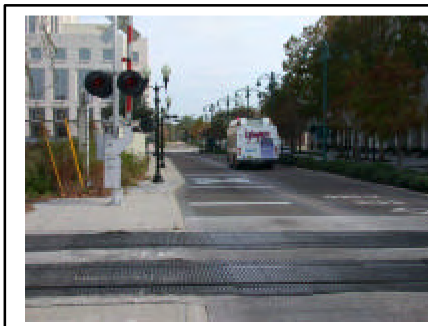
3.1.3.2 Median Lanes

Unlike curbside bus-only lanes, median bus-only lanes are much less likely to be congested by traffic. With traffic conflicts only at intersections, median bus-only lanes approach the performance of busways or even light rail systems. The need for customer loading areas in the center of the street can increase cross section street width. Central stations also require customers to cross traffic lanes to reach the sidewalk. This design can create safety problems for customers needing to cross several lanes of heavy traffic to access a station. In addition, left-turning vehicular traffic conflicts with buses going straight through the intersection to begin operating on the next segment of designated median runningway. Either left turns should be banned or they must be permitted only in a separate phase such as with the Vancouver B-Line. For these reasons, median bus-only lanes are among the most common choices for BRT systems operating on arterial streets including the systems in Curitiba, Euclid Corridor in Cleveland, 98 B-Line in Vancouver (shown), and Lane Transit in Eugene, Oregon.

Median Bus-Only Lane, Vancouver
Source: www.nbrti.org

3.1.3.3 Contra-flow Lanes

Contra-flow lanes are less common solutions for integration of BRT features with arterial streets. A contra-flow lane is typically a bus-only lane in the opposite direction on what would otherwise be a one-way street (i.e., contrary to the normal flow of regular traffic). Contra-flow lanes can sometimes provide more direct routing for buses when one-way street patterns create detours. Contra-flow lanes, even when implemented along the curb, do not generally have the same enforcement problems as curbside lanes. The Lymmo BRT system, located in Downtown Orlando, has segments of runningway that are contra-flow lanes. For most of its circular route, the Lymmo travels on former streets that were all one-way with three lanes in the same direction. After conversion to bus lanes, the right-most lane remained for vehicular traffic use. The center lane was converted to a bus-only lane with a



Contra-Flow Bus-Only Lane, Orlando
Source: www.nbrti.org

raised curb and streetscaping separating it from vehicular traffic. The left-most lane became a bus-only lane for opposite-direction (i.e., contra-flow) bus operation.

3.1.4 Mixed Traffic Lanes

Few BRT systems operate exclusively in mixed traffic. However, this can be a successful component part of many BRT systems mainly due to lack of right-of-way or political unwillingness to give up a travel lane for transit. In these conditions, the ITS element TSP and wide station spacing becomes especially important for increasing vehicle speeds in relation to other traffic. The Metro Rapid in Los Angeles employs these two BRT elements with great success to increase vehicle speeds while operating in mixed traffic. Even in mixed traffic, special vehicle signals and phasing via TSP in combination with dedicated queue jumper lanes can be used to give BRT vehicles priority at intersections. A queue jumper lane provides a faster means of bypassing congested sections of roadways and delays at intersections. A queue jumper lane involves a short section of roadway on an approach to a choke point, typically an intersection, designated for exclusive use of a BRT vehicle or for BRT vehicles and turning traffic only. A queue jumper lane thus allows BRT vehicles to "jump the queue" or bypass congestion. In some applications, a queue jumper lane is assisted by TSP to "permit" BRT vehicles to enter an intersection with a special signal ahead of other vehicles. This type of treatment is used by Lane Transit District in Eugene, Oregon for its EMX BRT system.

Mixed Traffic Operation, LA Metro Rapid
Source: http://www.nbrti.org

3.1.5 Planning and Implementation Issues

3.1.5.1 Availability of Right-of-Way

The most significant issue in planning BRT runningways is the availability of right-of-way, whether on an arterial, adjacent to a highway, or on a separate right-of-way. Dedicating space on existing roadways for either queue jumpers at congested intersections or an entire dedicated bus-only lane may require reallocation of roadway space from general travel lanes or parking. Given the potential community and business impacts, changes to the roadway structure need to be planned carefully.

3.1.5.2 Enforcement

Managing conflicts with other is important to maintain the integrity of any dedicated type of BRT runningway. Other vehicles crossing into the path of BRT vehicles or creating congestion in BRT lanes can introduce delays and create safety problems. Enforcing BRT runningways can be done passively through design (e.g., by physical barriers) or active police enforcement and judicious vehicle towing. Both types of enforcement require the participation of partners who implement highway design standards and police departments.

3.1.5.3 Dependability for Optimal Performance

The physical configuration of the runningway and construction materials affects the ability to operate, maintain, and repair it. Certain runningway treatments (e.g., optical, concrete curb guidance) may present operations issues in different conditions. For example, runningways must accommodate snow removal. And, the durability of painted pavement optical guidance markings on runningways may be affected by dust and extreme heat.

3.2 Stations

As the entry point for the BRT system, stations are a critical element in the design and provision of BRT services. BRT stations are much more than a sign attached to a pole as is typically the case with local services. At all or key stops along a BRT route, stations should provide a range of services and amenities that are customer-friendly and context sensitive by recognizing the unique characteristics of the area served by the BRT system. Stations options range from a simple stop with a well-lit basic shelter to the most complex intermodal center with a host of design features including parking and level boarding. Stations form the critical link between the BRT system, its customers, and other public transit services offered in the region. Stations are also the locations where the BRT system's brand identity can be distinguished from other public transit services.

3.2.1 Station Considerations

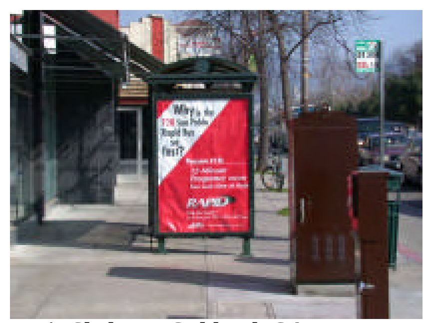
Station design must incorporate a number of different considerations. The first consideration is the relationship of the station to the character of the service being provided. The design of BRT stations can promote service effectiveness and efficiency by reducing delay and dwell time and by providing appropriate facilities and amenities for the given service pattern and market. The second consideration is the indirect impact of the station design on the overall perception or image of the system. A well-designed BRT station can include aesthetic landscaping, visibility, easy access and egress, seating, lighting, protection from the elements, security, and other "customer friendly" amenities. Furthermore, stations can incorporate a design motif that reinforces a unified design for the BRT system. Often, the integration of station design with vehicle design makes a powerful statement to customers about the identity of the system (i.e., the Metro Rapid in Los Angeles). These features enhance the image of BRT service and can potentially have positive impacts on ridership. Third, station design relates with the local environment in a way that promotes the overall quality and livability of the surrounding area. Integration into the local environment can include the use of specific aesthetic-design elements such as unique station canopies used in the Metro Rapid in Los Angeles, high-tech materials such as stainless steel used in the Silverline in Boston, historical references, and/or architectural themes used by the Lynx LYMMO BRT system in Orlando, Florida.

3.2.2 Station Type

There are several major BRT station types: basic shelter, enhanced shelter, designated station, and intermodal transit center. In increasing size and complexity, the station types range from very simple on-street shelters to rail-like intermodal transit centers. BRT stations should be designed to convey a brand identity that distinguishes the BRT system from other public transit services, portraying a premium-type service, while at the same time integrating with the local environment.

3.2.2.1 Basic Shelter

This is the simplest form of the four BRT station types listed within this section. It consists of a "basic" transit stop with a simple shelter to protect waiting customers from the weather. In general, this type of station has the lowest capital cost and provides the lowest level of customer amenities. In most cases, the shelter aspect of the station includes only a canopy and no side-walls.



Basic Shelter – Oakland, CA
Source: www.nbrti.org

3.2.2.2 Enhanced Shelter

The enhanced shelter BRT station design is an enhanced "on-street shelter." This BRT station type incorporates additional design features such as walls made of glass or other transparent material and customer amenities such as benches, trash cans, pay phones, or real-time information such next vehicle arrival.

Enhanced Shelter – Los Angeles, CA
Source: www.nbrti.org

3.2.2.3 Designated Station

The designated BRT station resembles a “rail-like” station in appearance and design. This station design generally includes level customer boarding and alighting and a host of customer amenities including ITS/APTS elements.

Designated Station, Brisbane Busway
Source: www.nbrti.org

3.2.2.4 Intermodal Transit Center

The intermodal transit center is the most complex and costly of the BRT stations. This type of BRT station is rail-like in design and appearance, has level boarding, provides a host of customer amenities including APTS/ITS elements, and accommodates the interchange of various other public transit modes with the BRT service.

Intermodal Transit Center, Ottawa Transitway
Source: www.nbrti.org

3.2.3 Station Location

BRT stations can be located on the near-side of an intersection, on the far-side or at mid-block. In general, far-side stops are preferable, especially when used with TSP. This allows much greater time for signal controllers to react to requests for priority and for BRT vehicles to clear the intersection. Far-side stops also reduce vehicle conflicts with right-turn movements that occur at near-side stops. Far-side stops also allow vehicles to use gaps in traffic created by the intersection for merging. For some of the stations in the Metro Rapid in Los Angeles use far-side stations exclusively in conjunction with TSP.

3.2.4 Platform Height

The platform height affects the ability of disabled or mobility-impaired customers to board the vehicle. Customers traditionally board vehicles by stepping from a low curb up to the vehicle steps. Given the trend of manufacturers and transit agencies to incorporate low-floor vehicles into their fleets in response to the Americans with Disabilities Act, boarding is easier for all customers. Raised curbs or level platforms have been introduced to BRT systems to facilitate boarding and reduce dwell time even more. Platforms at the same height as vehicle floors can enhance customer experience and reduce dwell times if some type of "precision docking" is provided that permits no-gap boarding and alighting.

3.2.4.1 Standard Curb

The standard curb causes a vertical gap between the height of the station platform or the curb and the vehicle entry step or floor. This causes customers to step up to enter the BRT vehicle and step down to exit it. In most instances, this type of platform treatment is used as a last resort when the station right-of-way cannot be altered.

3.2.4.2 Raised Curb

The raised curb platform height should be no more than 10 to 14 inches above the height of the BRT runningway on which the BRT system operates (this depends a lot on the vehicles used and vehicle clearance heights mandated by the State of Florida). In some cases, the raised curb will more closely match the height of BRT vehicle's entry step or floor to accommodate "near" level boarding. This treatment is preferred over the standard curb.

3.2.4.3 Level Platform

To create the safest, easiest, and efficient manner of customer boarding and alighting, platforms that are level with BRT vehicle floors (for example, 14 inches above the pavement for low-floor vehicles) are the preferred station platform treatment. Level station platform boarding and alighting platforms enhances the customers traveling experience by creating a seamless transition between station and vehicle.

Level boarding also reduces boarding time for all customers, but especially those with mobility impairments. Level boarding can be achieved by either lowering the floor of the vehicle (using low-floor vehicles), raising the level of the platform, or both. According to the Transit Capacity and Quality of Service Manual (TCRP, 2000), dwell times on low floor buses average 85 percent of the times on standard buses. When the need to cycle a wheelchair lift is avoided, many seconds of run time can typically be saved. The Curitiba BRT System pioneered level boarding with its innovative tube stations. Wheelchair lifts are provided at stations to assist the mobility impaired with the transition from sidewalk level to platform level prior to boarding a BRT vehicle. Buses are equipped with ramps that extend when the doors open to close the gap between the vehicle and the tube platform. The floor of the vehicle is at the same height as the platform. With modern low-floor buses, level boarding at stations can be achieved with relative ease. Precision docking technology is available to minimize the gap between the vehicle and the platform. For example, the TEOR BRT system in Rouen, France uses optical guidance to "dock" vehicles about 2 cm from the station platform edge to complete a seamless transition between the vehicle and station platform edge, as shown in the photo above.

Level Boarding - Rouen, France
Source: www.nbrti.org

Platform Layout

Platform layout also is a major element of station design. It affects how many vehicles can simultaneously serve a station and how customers must position themselves along a platform to board a vehicle.

3.2.4.4 Single Vehicle Length Platform

This is the shortest platform length necessary for the entry and exit of one BRT vehicle at a time at a station.

3.2.4.5 Extended Platform with Un-Assigned Berths

Extended platforms usually accommodate no less than two vehicles and allow multiple vehicles to simultaneously load and unload customers. Since this platform can accommodate more than one vehicle at a time, overlay services can more easily utilize the BRT stations and runningway.

3.2.4.6 Extended Platform with Assigned Berths

Extended platforms with assigned berths have all of the features of extended platforms but also assign vehicles serving specific routes to specific positions on the platform. This is the longest of the two platform length options.

3.2.5 Passing Capability

When BRT service on a runningway is so frequent that vehicles operate in quick succession, the ability of the vehicles to pass each other can maximize speed and reduce delay, especially at stations. Passing capability can be accommodated through a number of means including multiple lanes, passing lanes at stations or intersections, or ability to use adjacent lanes with mixed flow traffic. Having the ability for BRT vehicles in service to pass one another is important in two primary cases:

- In mixed flow operation, where frequency is high and travel times are highly variable
- In cases where multiple types of routes (local and express) operate along the same runningway and serve uneven levels of demand

In both of these cases, BRT vehicles can delay other BRT vehicles operating on the same runningway if there is no ability to pass one another.

Passing capability can be achieved using the pull-outs or passing lanes.

3.2.5.1 Bus Pull-outs

For both arterial BRT operation and exclusive lanes, vehicle pull-outs at stations allow buses serving a station to pull out of the BRT runningway and, thus out of the way of BRT vehicles needing to pass vehicles stopped at the stations.

3.2.5.2 Passing Lanes

For both arterial BRT operation and exclusive lanes, passing lanes at stations permit buses approaching a station to pass vehicles stopped at the stations.

3.2.6 Station Access

Station access describes how the BRT system is linked to surrounding communities and other modes within a family of transit services. Station access can be entirely focused on pedestrian access to adjacent land

Passing Lane – Ottawa Transitway
Source: www.nbrti.org

uses or can emphasize regional access through the provision of large parking garages and lots. The type of parking facility and the number of spaces should be tied to the nature of the market that the station serves and the adjacent physical environment. The provision of parking (park-n-ride, kiss-n-ride) at the appropriate BRT stations can save customers overall travel time and expand the reach of the system out into the wider community it serves.

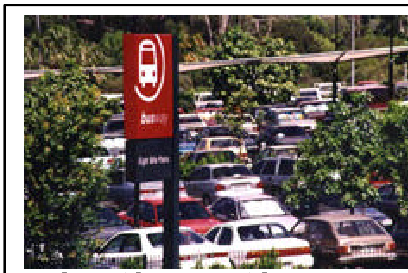
3.2.6.1 Pedestrian and Non-Motorized Linkages

Pedestrian linkages such as sidewalks, overpasses, pedestrian paths, bicycle lanes are important to establish physical connections from BRT stations to adjacent sites, buildings, and activity centers.

3.2.6.2 Park-n-Ride & Other Facilities

Park-n-ride and kiss-n-ride lots allow BRT stations (especially those without significant development) to attract customers from a wide area around the stations. Since the inherent flexibility of BRT allows it to be routed off of the primary runningway, regional facilities of this type can also be located off the runningway at shopping malls, churches, etc. This arrangement can link BRT service with existing parking lots, potentially reducing capital investment costs.

Unlike traditional local routes, BRT systems frequently accommodate multiple modes of access. BRT stations often accommodate bicycle, kiss-n-ride, park-n-ride facilities. Kiss-n-ride and park-n-ride are especially common on systems in outlying areas, such as the Houston HOV system and the Brisbane Busway. Station-area development is also important to enhancing ridership. Ottawa has achieved great success with integrating BRT stations with major shopping malls. The stations are built in the outer lots of the property and



Park-n-Ride Lot – Brisbane Busway
Source: www.nbrti.org

infill development is constructed between the stations and the mall. This improves the pedestrian connection between the BRT station and the mall. In addition, malls frequently offer considerable unused parking capacity that may be available for park-n-ride lots. Especially along arterial streets, many BRT customers will arrive by walking. Good pedestrian access including complete sidewalk networks, marked crosswalks, and pleasant walking environments are important for promoting access between BRT stations and surrounding trip generators and attractors.

3.2.7 Station Operational Issues

3.2.7.1 Station Location

The design and location of stations and stops in a BRT system can have a substantial impact on overall system performance. For descriptive purposes in this section, the term “station” and “stop” are interchangeable.

BRT system operating speeds are greatly influenced by a number of operational planning issues including the distance or spacing between stations. The spacing of stations has a measurable impact on the BRT system’s operating speed and, therefore, customer total travel time. Long station spacing increases operating speeds.

3.2.7.2 Station Spacing

Bus stop spacing has two possible impacts on BRT system customers. First, it reduces in-vehicle travel time. Second, it can negatively affect customers by requiring them to walk further to reach stops. Although analysis techniques based on acceleration rates, running speed, dwell time, etc. can determine optimal stop spacing, the most important criterion in selecting station locations is proximity to major activity centers or other locations along the planned BRT corridor with known or predicted high customer demand. Bus stop spacing varies considerably between BRT systems. BRT stations tend to be farther apart in suburban areas (usually one mile or more apart) than in urban areas (usually 0.25 to 0.5 miles apart), but not necessarily. For example, the South-Miami

Dade Busway operates in a suburban context parallel to a major arterial street and has stations spaced approximately every 0.5 miles. In Los Angeles, the station spacing for the Metro Rapid focuses primarily on major destinations and transfer points, with stop intervals approximately every 0.8 to 1.0 mile.

In more urban contexts, systems show similar variability. The Euclid Corridor Busway in Cleveland has approximately 3 stations per mile (every 0.33 mile) and the Ottawa Transitway has an average station spacing of approximately one station per kilometer (every 0.6 mile), with stops clustered closer together in the central city and farther apart in the suburbs. In Vancouver, the 98 B-Line has stations spaced about every 0.8 mile.

3.2.7.3 Limited Stop Service

One way to maintain close station spacing and reduce travel time is to skip stations/stops along the route. The Los Angeles Metro Rapid replaced existing limited-stop service and left existing local service unchanged along the Wilshire-Whittier corridor. Some BRT system runningways are constructed to allow buses to pass each other at stations. Passing provisions are a necessary physical component of any skip-stop service pattern. Limited stop service is covered in greater detail in the section related to operation and service planning.

3.2.8 Station Implementation Issues

The flexible and diverse nature of BRT presents unique issues and challenges related to station design and implementation.

3.2.8.1 Availability of Property

Just as the availability of right-of-way is an issue in the implementation of runningways, the availability of physical property for stations is a key factor in station planning and BRT routing. BRT routes that use curb lanes or operate in mixed traffic along arterials typically serve stations sited at the street's edge and/or on sidewalks. Clearance for pedestrian and wheelchair traffic must be accounted for in the design of stations. In some cases, additional street right-of-way is required either through partial lane realignment or sidewalk extension ("bulb out"). Transit planners and engineers must balance the needs of parking, general traffic lanes, and BRT stations. Finally, in exclusive runningway sections, additional property will be required to build enhanced stations.

3.2.8.2 Pedestrian Access and Safety

Care must be taken to minimize the conflict between pedestrians and BRT vehicles in and around stations. The need to develop a strong linkage for pedestrians and wheelchairs to adjacent communities will affect the site layout for BRT stations. Because station platforms typically are not significantly higher than the runningway through the station, there is a risk of pedestrians walking into the path of an oncoming BRT vehicle to cross from one platform to another. Similar conflicts between pedestrians and BRT vehicles may occur at crossings between the BRT runningways and cross streets. Some BRT designs incorporate elements that minimize this conflict. For example, the Southeast Busway in Brisbane, Australia provides overhead walks to access/egress stations for increased customer safety. The overhead walks were also provided as a result of physical station location space limitations.

3.2.8.3 Safety and Security

Design at stations should account for the possibility of crime or other security threats. ITS elements to deter crime include surveillance cameras and equipment, emergency call boxes, and closed-circuit television monitoring. Extensive lighting and/or illumination should also be used. Passive methods of incorporating security into the design focus on openness, high visibility, and intense lighting. Such design approach focuses on unobstructed sight lines that enable BRT customers to have unobstructed views of their surroundings and can be seen within and outside of the facility by others.

3.2.8.4 Community Integration – Contextual Design

As the primary entry point into the BRT system, stations provide the first impression to customers and are the primary connection between the BRT system and the surrounding community. Station aesthetic design and pedestrian connectivity to the surrounding community are critical in conveying a positive identity for the BRT system. The following are important issues to consider when designing stations that integrate into the local community: BRT system integration into an urban or suburban setting provides an opportunity to beautify the area around runningways and stations with streetscaping, landscaping, and other improvements such as lighting, sidewalks, street furniture, and public art including statues and other art objects similar to the Metrorail and Metromover platforms.

3.2.8.5 Planning and Zoning

Planning guidelines and zoning regulations define the intensity and character of the existing and potential transit oriented development (TOD) around a station. When planning a BRT station, it is important to account for planning/zoning in order ensure that station design is incorporated with current and future development.

3.2.8.6 Advertising

Transit agencies often incorporate advertising to earn additional revenue. Given this, BRT station design can incorporate provisions for print or electronic advertising that balance a transit agency's revenue generation goals with the BRT system's aesthetic requirements and surrounding community. However, due to the jurisdictional nature of some BRT routes, each jurisdiction may have regulations governing advertising on transit stations.

3.3 Intelligent Transportation Systems (ITS)

A wide variety of ITS technologies can be integrated into BRT systems to improve BRT system performance in terms of travel times, reliability, convenience, operational efficiency, and safety and security. ITS includes vehicle priority, operations and maintenance management, operator communications, real-time customer information, and safety and security systems. In fact, vehicle priority or TSP is one of the most prevalent ITS technologies deployed in the BRT environment. The majority of North American transit systems are implementing or planning TSP as an important element of their BRT systems.

ITS has helped transit agencies increase safety, operational efficiency, and quality of service. It includes a variety of advanced technologies to collect, process, and disseminate real-time data from vehicle and roadway sensors. The data are transmitted via a dedicated communications network and computing intelligence is used to transform these data into useful information for the operating agency, driver, and most importantly the customer. Different combinations of technologies combine to form different types of ITS systems. For example, Automatic Vehicle Location (AVL) in combination with Automated Scheduling and Dispatch (ASD) and TSP can improve schedule adherence and hence reliability as well as the average speed of BRT vehicles in revenue service.

Command Center - Brisbane Busway
Source: www.nbrti.org

ITS provides many BRT system performance improvements and benefits. The remote monitoring of BRT vehicle location and status and customer activity also improves customer and facility safety and security. ITS also can be used to assist operators in maintaining vehicle fleets and alert mechanics to impending mechanical problems as well as routine maintenance needs.

ITS applications are fundamental to generating many of BRT's benefits. However, integration of individual ITS into the overall BRT system is essential. Combinations of ITS applications must ultimately work together to provide the high-quality service which defines BRT.

3.3.1 Characteristics of ITS

There are many ITS technologies that can be utilized for BRT systems. In this section, individual ITS technologies applicable to the MDC BRT program are discussed. Some of the ITS technologies discussed may be too sophisticated for the initial MDC BRT program including precision docking and vehicle guidance. However, they are discussed as having future potential as the MDC BRT program expands. Many of the ITS technologies discussed have already provided significant benefits as part of operating BRT systems around the world. They have been categorized into five groups:

- Transit signal priority or TSP
- Assist and automation technology
- Electronic fare collection
- Passenger information
- Safety & security

.

3.3.2 Transit Signal Priority

There are several possible types of traffic signal priority (TSP) treatments applicable to BRT. These range from the simplest passive priority to the most sophisticated adaptive/real-time control. Basically, TSP involves giving priority to buses at intersections by extending the green cycle (holding a green light for a vehicle), red truncation (giving an early green signal to an approaching vehicle), or allowing buses to proceed first from the intersection using a special signal phase. TSP requires traffic signal controllers and software and TSP capable equipment on the transit vehicle and at the intersection for identifying the transit vehicle and generating low priority request when appropriate. The objectives of TSP include reduced travel time, improved schedule adherence, improved transit efficiency, contribution to enhanced transit information, and increased road network efficiency.

TSP strategies vary widely in their benefits and costs, applicability as well as limitations. According to *Advanced Public Transportation Systems Deployment in the United States Year 2000 Update*, there is an 87 percent increase in the numbers of transit agencies with operational TSP systems from year 1998 (16 agencies) to year 2000 (30 agencies). New advances in traffic/vehicle detection and communication technologies, and well-defined priority algorithms have made TSP more appealing and acceptable.

It should be stressed that the successful implementation of TSP cannot be accomplished without full cooperation and coordination from traffic management authorities (Florida Department of Transportation and Dade County Public Works) 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 increases in non-transit vehicle delays at intersections. All stakeholders need to be involved throughout the MDC BRT program to ensure that system performance outcomes are consistent with project goals and objectives.

3.3.3 Assist & Automation Technology (AAT)

AAT includes technologies that provide automated controls for lateral steering, starting, speed control, sand stopping for BRT vehicles. For use in the MDC BRT program, several AAT technologies are discussed below. It should be noted that the list of AAT technologies included is not inclusive. AAT can also include collision avoidance and warning systems, for example.

3.3.3.1 Precision Docking

This AAT technology assists drivers to correctly place a BRT vehicle at a station location both latitude and longitude. There are two primary ITS-based methods to implement precision docking: magnetic and optical. This requires the installation of markings on the pavement (paint, magnets), vehicle-based sensors to read the markings, and linkages with the vehicle steering system. The availability of these systems is somewhat limited and optical guidance is limited to international suppliers as an additional option for new vehicle purchases. The French CIVIS system uses an optical guidance system that employs a video camera and an image processing algorithm to follow special painted markings designating the intended vehicle path. In the US, the Las Vegas Regional Transportation Commission (RTC) implemented a precision docking system utilizing the French CIVIS vehicle for its MAX BRT service that operates on the Strip.

3.3.3.2 Vehicle Guidance

This AAT technology guides BRT vehicles on the actual runningway. These technologies, also known as "lane assist technologies," allow BRT vehicles to operate safely at both low and high speed. There are three primary vehicle guidance technologies: magnetic, optical, and GPS-based. They either require the installation of markings on or imbedded in the runningway pavement (paint, magnets) or development of a GPS-based route map. They also require vehicle-based sensors to read the markings, and linkages with the vehicle's steering mechanisms.

"Optical" Vehicle Guidance - Rouen, France
Source: www.nbrti.org

3.3.4 Electronic Fare Collection

Electronic fare collection or EFC supports efficient vehicle boarding (customer streaming) for BRT systems. The ultimate goal of EFC is to control how fares are physically paid, processed, and verified. EFC can influence a number of system characteristics including service times (dwell time and reliability), fare evasion and enforcement procedures, operating costs (labor and maintenance), and capital costs (equipment and media options). The various fare collection processes associated with EFC are discussed in Section 3.6 of this technical memorandum.

The Washington Area Metropolitan Transit Authority (WMATA) recently installed "smart" fare boxes on its Metrobus fleet that are capable of reading SmarTrip cards, WMATA's version of the Smart Card. SmarTrip is a permanent, rechargeable fare card. It is made of plastic similar to a credit card and is embedded with a special computer chip that keeps track of the dollar value on the card. The new fare boxes accept the SmarTrip card for fare payment, transfers between Metrobuses and transfers from Metrorail to Metrobus. If they elect, customers can still pay fares traditionally with cash, passes, and tokens.

3.3.5 Passenger Information

For BRT systems, information about the vehicle schedule can be provided to the customer at stations or on vehicles. Provision of this information about BRT vehicle schedules, next vehicle information or delays within the system can improve customer satisfaction by reducing platform wait time anxiety.

Info at Station – Oakland, CA
Source: www.nbrti.org

3.3.6 Safety & Security

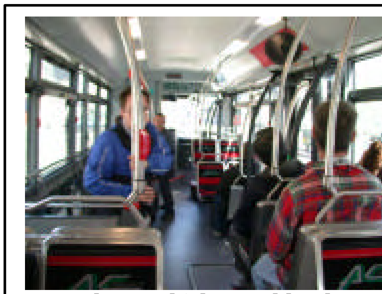
Use of silent alarms and on-board and in-station closed-caption television video monitoring systems (CCTV) can increase the security of the overall BRT operation.

Specific types of technologies include silent alarms installed on the BRT vehicle that are activated by the BRT vehicle operator. A message such as "Call 911" can be displayed on the exterior sign board for others to see or messages can be sent back to the operations center to indicate an emergency or problem. Also, surveillance of the BRT system can be accomplished by use of CCTV at stations and vehicles. Via CCTV, real-time data are sent to a central operations center for continuous monitoring.

3.4 Vehicle Design

Vehicle design provides one method for differentiating BRT service from traditional local service. BRT vehicles have a direct impact on speed, capacity, the environment, and customer comfort. They can also be the one element of the BRT system that most customers and non-customers associate with the system's branding and identity. As the BRT element in which customers spend the most time, they derive much of their impression of the system from experience with vehicles. For non-customers, vehicles are the most visible system element (along with stations and runningways). In Curitiba, Brazil, its BRT system is characterized by bright red, bi-articulated vehicles capable of level boarding at tube stations. The French CIVIS is a sleek, futuristic rail-looking vehicle with very large side windows, low-floor design, roof sky lights, and electric propulsion. Each of these examples uses the design of the vehicle to create a large part of the system's identity.

3.4.1 Low-Floor Design



Low-Floor Vehicle – Oakland, CA
Source: www.nbrti.org

Low-floor vehicles are used in many of the existing and planned BRT systems in the US. As described in other sections of this tech memo, low-floor vehicles support near-level or level boarding which reduces station vehicle dwell time. In response to the Americans with Disabilities Act (ADA), low-floor vehicles have become the norm in conventional transit operations. Vehicles in US BRT applications range from low-floor two-axle 40- or 45-foot units to three-axle 60-foot articulated buses. Low-floor vehicles are also popular with BRT systems because their availability from many vendors ensures price competition in procurement, both initially and in the future.

3.4.2 Door Capacity

BRT systems that use off-board fare payment methods are able to reduce dwell time by allowing customers to board and alight through multiple doors. Some vehicle designs include three doors in a standard 40-foot vehicle and more doors in articulated vehicles. In addition, wider doors, in some cases with more than 48 inches of clearance width, speed the boarding and alighting process by allowing greater customer throughput.

3.4.3 On-Board Amenities

BRT vehicles often offer upgraded interior materials and finishes, including upholstered seats and individual air vents. More comfortable seat designs are especially common on systems that provide longer trips. The use of AVL systems on BRT vehicles not only improves dispatching efficiency and supports customer information systems at stations, but also can interface with next-stop annunciators and variable message signs. The incorporation of larger windows (especially on specialized BRT vehicles) and interior light fixtures that allow for abundant illumination day or night to provide an "open feeling" can improve the perception and reality of customer security. Large windows have become an important vehicle design reference for most transit agencies due to perceived customer security.

3.4.4 Propulsion System

BRT vehicle manufacturers offer a number of viable propulsion technologies ranging from clean diesel to compressed natural gas (CNG) to hybrid-electric systems to fully-electric systems. Supported by regulations for cleaner air, transit agencies have a large number of choices concerning vehicle propulsion technology. Propulsion technology is evolving to provide new systems that use cleaner, alternative fuels and new controls on emissions, resulting in reduced pollution and noise emissions.

3.4.5 Design & Appearance

The design of the French CIVIS vehicle gives the BRT systems that employ it a unique physical identity similar to light rail systems. The use of vehicle design and appearance to market the BRT service is a common practice among many current BRT systems. One good example of this marketing tactic is how the Metro Rapid in Los Angeles is packaged. It uses conventional low-floor CNG vehicles painted in a special bright red color (Ferrari Red). The Metro Rapid livery and logo were designed to specifically connote speed. They are prominently displayed on all Metro Rapid vehicles and stations to give the system a unique and attention grabbing appearance.

There are a number of possible BRT vehicle configurations or designs that were identified during the review of literature. Many of these vehicles are in use worldwide and have provided significant benefits as part of the systems that utilize them. They are categorized into five groups:

- Conventional standard
- Stylized standard
- Conventional articulated
- Stylized articulated
- Specialized vehicles

3.4.5.1 <u>Conventional Standard</u>

Conventional Bus - LA Metro Rapid
Source: www.nbrti.org

Conventional standard vehicles are 40-45 feet in length and have a conventional looking style, i.e., like a bread box on four wheels. The partial low-floor variety has a step near the rear of the vehicle. This vehicle is currently the in-service norm among most transit agencies. This vehicle typically has at least two doors (one front and one rear – both right side) and a deployable wheel chair ramp.

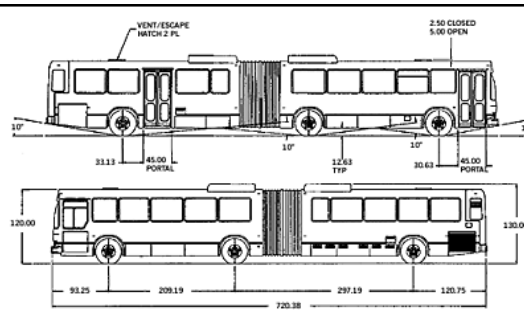
3.4.5.2 Stylized Standard

The stylized standard vehicle has all of the features of a conventional step-low-floor vehicle. However, the major difference is that it incorporates slight body (usually the front end) modifications or additions to make the body appear more modern, aerodynamic, and attractive to customers. An example of this type of vehicle is the Van Hool operated by AC Transit in Oakland, CA as part of its San Pablo Rapid BRT system.

Stylized Standard Vehicle - Oakland, CA
Source: www.nbrti.org

3.4.5.3 Conventional Articulated

This articulated vehicle has a greater customer carrying capacity than either of the two standard vehicles. Typical floors are partial-low with steps with two or three doors. Articulated vehicle seating capacity depends heavily on the number and placement of doors and arrangement of the seats. An example of this type of vehicle is the Neoplan AN460-LF (at right) used as part of the Boston Silverline BRT.



Conventional Articulated Vehicle
Source: www.neoplanusa.com

3.4.5.4 Stylized Articulated

This type of vehicle is just now emerging in the US in direct response to the demands of transit agencies for vehicles that are more modern, sleek, and comfortable than standard or conventional vehicles. These vehicles incorporate step-low floors, at least three wide doors, and rapidly deployable wheel chair ramps to facilitate boarding and alighting to decrease stop dwell times as much as possible. The NABI 60 shown below is an example of a stylized-articulated BRT vehicle. The Los Angeles County Metropolitan Transportation Authority's (LAMTA) has ordered 200 North American Bus Industries (NABI) 60s for use on its expanded Metro Rapid BRT program.

Stylized Articulated Vehicle
Source: www.nabiusa.com

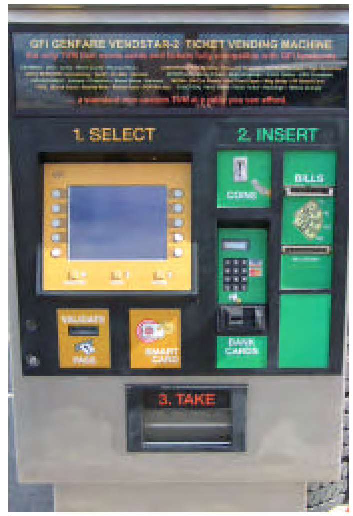
3.4.5.5 Specialized Vehicles

This vehicle employs a modern, aerodynamic body that has a look and feel to it similar light rail vehicles. It also employs advanced propulsion systems and often comes equipped with advanced ITS and guidance systems. Examples of specialized vehicles are the French-made CIVIS shown below and the Dutch-made Phileus.

CIVIS Specialized BRT Vehicle
Source: www.irisbus.com

3.5 Fare Collection

Fare collection systems in use on BRT systems range from traditional on-board vehicle fare boxes to proof-of-payment (POP) systems common on light rail systems to barrier systems common on heavy rail systems. The use of POP significantly reduces dwell time at stations. With POP, customers no longer need not queue at the front door of the vehicle to pay fares and board. According to the *Transit Capacity and Quality of Service Manual* (TCRP, 2000), off-board pre-payment reduces per customer boarding times by up to 33 percent compared to systems that require cash payment and operator interaction. The most common approach to off-board fare pre-payment is proof-of-payment (POP). The Ottawa Transitway, Vancouver's 98B-Line BRT, and the MAX in Las Vegas use proof-of-payment systems. TCRP Report 10 - *Fare Policies, Structures, and Technologies* - ranked proof-of-payment highest among fare collection systems, including payment-on-entry and barrier systems. The only criterion on which proof-of-payment was considered inferior to other systems was "impact on fare evasion or abuse." Systems vary on the extent to which they use random fare checks to limit fare evasion. Barrier systems are used in Curitiba, Brazil and Bogotá, Colombia. In these systems customers pay their fare at the station before entering the waiting area to board vehicles.



Off-Board Ticket Vending Machine – RTC, Las Vegas
Source: www.nbrti.org

3.6 Operation and Service Planning

The design of the service and operations plan for BRT service affects how a customer finds value in and perceives the service. BRT service needs to be frequent, direct, easy-to understand, comfortable, reliable, operationally efficient, and above all, rapid. The flexibility of BRT elements and systems leads to significant flexibility in designing a service plan to respond to the customer base it will serve and the physical and environmental surroundings in which it will operate.

This section discusses some of the basic service and operational planning issues related to the provision of BRT service. It should be noted that each of the operational items discussed vary when applied in different corridors, cities, and regions depending on a host of factors such as available capital and operating funds, customer demand, rights-of-way, route configuration, and political environment.

3.6.1 Characteristics of Operation & Service Planning

The review of literature uncovered that there are too many dynamic issues to cover with regard to operation and service planning for BRT to be able to fit them all into this section. As a result, only the basic ideas applicable to MDC related to BRT operation and service planning are touched on in this section.

3.6.2 Route Length

The route length affects what locations a customer can directly reach without transferring as well as determining the resources required for serving the route. Longer routes, while minimizing the need for transfers, require more capital and labor resources and encounter much more variability in operations. Short routes may require customers to transfer to reach locations not served by the route but can generally provide higher travel time reliability. BRT service need not operate on dedicated facilities for 100 percent of their length, but rather can operate over a combination of runningway types.

3.6.3 Route Structure

An important advantage of BRT runningways and stations is that they can accommodate different vehicles serving different routes. This flexibility allows for the incorporation of different types of routes and route structures with the same physical investment. Managers of BRT systems are thus able to provide point-to-point service or "one-seat rides" to customers thereby reducing overall travel time by limiting the number of transfers. Offering point-to-point service with limited transferring will assist with attracting choice riders to the BRT system. There is a trade-off to consider when considering different route structures. Simple route structures with just one or two route patterns are easy for new customers to understand and, therefore, straightforward to navigate. In order to attract customers, they must be able to easily understand the service being offered. Service directness and linearity in routing are keys to providing customers with a clear understanding of the BRT service. On the other hand, providing additional options, such as through a comprehensive route network with branching routes, gives customers more choices, especially those customers who might otherwise transfer. Clarity and choice are two principles that need to be balanced when determining the route structure. Different route structures also pose different opportunities for restructuring other transit services. Simple route structures may allow for connecting transit services to be focused on a few stations. Development of branching networks may allow for existing services to be restructured and resources to be reallocated from routes now served by BRT services to other routes.

3.6.4 Service Span

The service span represents the period of time that a service is available for use. Generally, rapid transit service is provided all day with high frequencies through the peak hours that allow customers to arrive randomly without significant waits. Service frequencies are reduced in off-peak hours such as the mid-day and late evening. Service spans affect the segment of the market that a transit service can attract. Long service spans allow patrons with varied schedules and many different types of travel patterns to rely on a particular service. Short service spans limit the market of potential customers. For example, peak only service spans limit the potential customers served to commuters with daytime work schedules. Where local and BRT services serve the same corridor, the service span of both local and BRT service may be considered together since customers may have an option between the two services.

3.6.5 Service Frequency

The service frequency directly determines how long customers must wait at stations for BRT vehicles. Tailoring service frequency to the market served is one of the most important elements in planning and operating a BRT system.

3.6.6 Station Spacing

BRT system operating speeds are greatly influenced by a number of operational planning issues including the distance or spacing between stations. The spacing of stations has a measurable impact on the BRT system's operating speed and customer total travel time. Long station spacing increases operating speeds but may require customers to walk greater distances to access stations.

3.6.7 Schedule-Based Control

Schedule-based control regulates the operation of vehicles to meet specified schedules. Operating policies dictate that operators must arrive within a certain scheduled time at specific locations along the route. Dispatchers monitor vehicle locations for schedule adherence. Schedule-based control facilitates connections with other services when schedules are coordinated to match. Schedule-based control is also used to communicate to customers that schedules fall at certain regular intervals.

3.6.8 Headway-Based Control

Often used on very high frequency systems, headway-based control focuses on maintaining headways, rather than meeting specific schedules. Operators may be encouraged to travel routes with maximum speed and may have no specified time of arrival at the end of the route. The only goal of the vehicle operator is to arrive at the end of the line as quickly and safely as possible. In some BRT systems that use this type of control, vehicle operators are encouraged to pass one another to reach the end of the line. In some BRT systems, control center staff monitors vehicle locations and issue directions to speed up or slow down in order to regulate headways and capacity, minimizing wait times and vehicle bunching.

3.6.9 All Day Span of Service

All day BRT service is usually provided from the start of service in the morning to the end of service later in the evening. This type of service usually maintains consistent headways throughout the entire span of service, even in the off peak periods. Expanding service to weekend periods can reinforce the idea that BRT service is an integral part of the transit network.

3.6.10 Peak Hour Only Span of Service

This type of BRT span of service option provides only peak hour service. Peak hour only service offers high quality and capacity BRT service only when it is needed during the peak hours. At other times, the base level of service may be provided by local routes.

3.6.11 Single Route Structure

This is the simplest BRT service pattern and offers the advantage of being easiest to understand since only one type of service is available at any given BRT station.
This route structure works best in corridors with many activity centers that would attract and generate customers at stations all along the route.

3.6.12 Overlapping Route with Skip Stop or Express Variations

The overlapping route with skip stop or express variations provides various transit services including the base BRT service. This type of routing offers the advantage of offering express or skips stop service to customers traveling between particular origin-destination pairs. This route structure works best with passing lanes at stations.
Including a high number of routes may cause confusion on platforms for infrequent riders and may cause congestion at stations.

3.6.13 Integrated or Network System

The network system route structure provides the most comprehensive array of transit services in addition to the base all-stops, local BRT service. This type of route structure provides the most options to customers for a one-seat ride but can result in customer confusion and vehicle congestion pulling into and out of stations.

In general, the structures of the routes correlate with the level of investment in the runningway infrastructure. Projects that operate using arterial lanes, either in mixed flow or designated bus-only lanes were implemented either as a single BRT route replacing an existing local route or as a single BRT route traversing the same route as a local route. Boston's Silver Line BRT is an example of a project where the BRT service totally replaced a local route. The station spacing remained relatively low at one station spaced every 0.22 directional route mile. Most other arterial BRT systems (AC Transit's Rapid Bus, Las Vegas' RTC's MAX, Los Angeles' Metro Rapid) involved an overlay of the BRT route on the local service. Station spacing for these BRT systems was between 0.5 and 1.0 miles. BRT Systems involving exclusive lanes (South Miami-Dade Busway and Pittsburgh's grade-separated busways) operate with integrated networks of routes. In these cases, one route functioned as the base service while other routes combine local feeder operation off the busway and express operation on the exclusive busways.

Frequency (headway) also correlates with the runningway investments. BRT systems on arterials operate with wider headways. Pittsburgh's exclusive busways demonstrates a very narrow headway along the trunk busway. Except for Phoenix, where the Rapid service operates as a peak-hour only commute service, all BRT systems operate during the same service span and all days of the week as the rest of the transit system network.

4. Recommendations for Miami-Dade County (MDC)

This section interprets some of the key findings from the literature review. Nothing in the literature describes each BRT element in terms of its relative net cost or benefit if implemented, such as cost per new rider or gain in net new riders as a result of TSP, for example. Such measures, while providing good indicators of which elements to include or not include in a BRT system, are difficult to quantify in isolation and have not been the focus of any research reviewed. Given this lack of information, this effort takes a slightly less rigorous, but similarly intentioned "sketch planning" approach. Firsthand knowledge of the proposed BRT corridors in MDC is utilized with regard to the potential of each major BRT element described in the literature review in terms of applicability to the MDC operating environment, contribution to the success of other BRT systems that employ each major element, and relative cost of implementation while balancing relative benefits. The objective is to identify those elements that could be highly desirable, implementable, and cost-effective elements of the MDC BRT program.

In the Section 4.1, BRT elements are grouped into those which should be included as part of the 11 proposed MDC BRT corridors. It needs to be kept in mind that some major elements may be applicable to only one corridor but not to others. Those major BRT elements that would provide additional benefits if substantial additional resources could be secured are also listed.

4.1 Elements Recommended for all MDC BRT Corridors

The following sections detail the BRT elements recommended for the proposed 11 corridors in the MDC BRT program. The recommendations are grouped by major BRT element, when possible.

4.1.1 Runningways

It is recommended that runningways be implemented that are clearly identifiable, free from traffic interferences wherever possible, and permit rapid and reliable BRT service. The MDC BRT program should make the best use existing arterial streets wherever existing conditions permit. Enhancing BRT vehicle speeds and service reliability should be a top priority. This can be accomplished by the operating in mixed traffic or engineering curbside or median bus-only lanes and, in some cases, may require major improvements to arterial streets to implement dedicated runningways. The literature review notes that BRT route alignments should be as direct and linear as possible by minimizing or eliminating vehicle turns. In conjunction with mixed-traffic running or arterial bus-only lanes, queue jumper lanes should be provided where there is major traffic congestion at intersections; a sufficient level of service (30 vehicles per hour, for example) to warrant them; favorable intersection geometry; and perhaps most important, a community willingness to support public transport, reallocate road space as needed, provide necessary funding, and enforce regulations.

No matter the combination of runningways implemented as part of the MDC BRT program, the runningways should provide a clear and strong sense of identity for the BRT system. This consideration is especially important where buses operate in arterial curbside or median bus-only lanes. It is recommended that runningways be clearly identifiable to traffic by marking/signing and/or painting it a special color (e.g., red, green, orange, yellow). For example, in Auckland, New Zealand, arterial curbside bus-only lanes are painted bright green and in Rouen, France the runningway for the TEOR BRT is painted bright red to denote their presence.

Based on the detailed analysis of the 11 potential BRT corridors, it is proposed that initially the MDC BRT program be modeled after the Metro Rapid in Los Angeles. The Metro Rapid integrated system of BRT features include simple and linear route layouts that are easy to operate and understand from the customers' viewpoint; very frequent service with headways as short 1.5 to 3 minutes for all or a significant portion of the service span; wide station spacing (about 1 mile apart); distinctive, easily identifiable bright red-colored, low-flow, environmentally-friendly vehicles that permit near-level customer boarding and alighting; simple and aesthetically pleasing stations with next vehicle arrival information displays, and TSP allowing vehicles to extend or advance the green cycle at most intersections. The Metro Rapid makes use of far-side stations. Initially, overlaid local MTA bus service was relegated to using near-side stops only to keep it separate from the Metro Rapid; however, this policy has recently been revisited by the LAMTA. Where space permits on newly-implemented Metro Rapid routes, new stations will be placed far-side and will be designed to accommodate both local buses and BRT vehicles. This design and operational feature should be considered and evaluated by the MDC BRT program during the initial planning stages.

One important consideration is the integration of traffic engineering and transit operations/planning. Traffic engineers and transit planners should work closely together in developing runningways as well as implementing other elements within the BRT corridors such as the location of stations and application of traffic controls such as TSP and special transit signalization. Based on firsthand knowledge of the 11 proposed BRT corridors, the specific traffic/transit engineering/planning techniques will vary with the type and location of the BRT runningways.

4.1.2 Stations

4.1.2.1 Pedestrian Access and Linkages

There are numerous locations along the 11 proposed BRT corridors where continuous sidewalk networks are absent or are in need of repair. It is recommended that high-quality pedestrian connections between BRT stations and adjacent traffic generators be constructed to maximize access and egress (i.e., ridership). In addition, good connections between BRT stations and intersecting local routes will be required. To support bicycle access, it is recommended that bicycle racks be provided at each BRT station and possibly on board vehicles (ether inside or on the front – this may necessitate limiting bicycle access to off peak times to minimize impact on dwell time). Last, it is recommended that at major off-street facilities (near or at the outbound end-of-the-line station at a minimum) where ample space permits, park-n-ride and kiss-n-ride facilities be provided.

4.1.2.2 Level Boarding

It is recommended that the MDC BRT program permit level or near-level transitions between the vehicle floor and the station platform. This can be achieved by using low-floor vehicles or raised boarding platforms with existing vehicles. It is common knowledge in the transit industry that level boarding reduces customer boarding time. By eliminating the need for wheelchair lift deployment, boarding time for the mobility impaired can be substantially reduced as well. Ramps on vehicles that deploy automatically at each station for all users (such as in Curitiba) would make boarding and alighting even faster. At the time of this writing, low-floor buses are available from many North American manufacturers.

4.1.2.3 High-Quality Stations

As discussed above, part of the premium service provided by a BRT system is experienced in customer facilities. It is recommended that MDC BRT stations consist of larger, distinctively designed shelters that provide not only ample overhead weather protection, but also vertical windscreens. Roofs should be extended over the vehicle boarding areas to shield customers from the sun and rain. A number of station amenities should be provided including lighting, trash receptacles, seating, pay phones, and/or newspaper vending machines, to name but a few. Platforms should be raised slightly above sidewalk level to accommodate near-level or level boarding. Wheelchair ramps should be provided at all stations to make the transition between sidewalk and station platform level. Designs may need to be varied from location to location similar to Metro Rapid in Los Angeles to accommodate available space constraints. In Los Angeles, the station that is ultimately constructed (there are three different "kits" to choose from) is determined by the available space at sidewalk/curbside. To accommodate POP fare collection, each station should be equipped with a fare card reader, much like the mechanism used on board current MDT buses. This fare card reader will allow customers to validate fare cards before boarding vehicles. For those who need to recharge their cards or purchase a single-use ticket, vending machines should be located on board the vehicle or at stations.

High-Quality Station – Brisbane SE Busway
Source: www.nbrti.org

4.1.3 Vehicles

The package of BRT and its supporting transit services will require a variety of vehicle types. To minimize requirements for maintenance training and spare parts storage, the vehicle types selected should match vehicles currently in use by MDT as much as possible. Since the BRT system will operate primarily on arterial streets in mixed traffic, the use of advanced transit vehicles that offer such features as automatic guidance systems, precision docking, bi-articulations, and two-sided boarding is not warranted. It is evident that the tremendous success of LAMTA's Metro Rapid that an innovative and effective BRT service can be implemented using "conventional" low-floor transit buses painted with a unique livery.

As ridership grows beyond the initial capacity of the BRT corridors, it is recommended that capacity be added in the form of articulated or bi-articulated vehicles and/or increased frequency. Low-floor articulated vehicles like the NABI 60 currently coming to market can accommodate increased customer loads. Exhibit 1 shows hypothetical examples of BRT service options and route capacity utilizing various vehicle types.

EXHIBIT 1: Examples of Service Options and BRT Route Capacity

Vehicle Type	Seated Capacity	Schedule Capacity	Headway (minutes)	Vehicles per Hour	Capacity (pphpd)
40' low-floor	34	43	10	6	255
60' low-floor articulated	58	73			435
75' low-floor bi-articulated	70	88			525
40' low-floor	34	43	5	12	510
60 ' low-floor articulated	58	73			870
75' low-floor bi-articulated	70	88			1,050
40' low-floor	34	43	3	20	850
60 ' low-floor articulated	58	73			1,450
75' low-floor bi-articulated	70	88			1,750

Note: pphpd equals passengers (customers) per hour per direction and schedule capacity assumes 25 percent for standees.

4.1.4 Intelligent Transportation Systems and Fare Collection

4.1.4.1 Off-Board Fare Pre-Payment

It is recommended that some type of an off-board vehicle proof-of-payment (POP) fare collection system be implemented for its BRT routes. This method is currently being used on the majority of light rail systems in North America and is an important element of several BRT systems in South America and Europe. The transit industry reports that operating costs are generally lower than for traditional pay on-board systems since the burden of fare payment is placed on the customer. However, there may be added capital cost and the expense of adding staff to conduct random fare checks. Fare evasion is also slightly higher with off-board fare POP systems. However, increased ridership due to improved customer convenience and reduced travel times can more than offset the additional operating costs. Metro-Dade Transit (MDT) currently uses a pay on-board system involving a fare box or a processing unit for tickets, cards, and cash adjacent to the operator at the front door of the vehicle. One advantage of this system is that it does not require significant fare collection infrastructure inside or outside the vehicle. Requiring customers to board only through the vehicle's front door to pay fares results in significant dwell time at stations, however. By eliminating queuing at the front door as customers handle cash and pay fares and by allowing entry through any door on the BRT vehicle, dwell time at stations will be substantially reduced improving BRT vehicle average speed. Customers needing to add value to fare cards could do so at vending machines at stations or on board vehicles. Fare evasion could be minimized by equipping personnel with fare card readers that check the time and location of the last validation stamp and by performing random, but sufficiently frequent, on board checks. Despite their additional cost, fare evasion checkers may, however, also serve to support the security of the system.

It is also recommended that an off-board vehicle barrier enforced fare payment system (i.e., pay-on-entering and/or exiting a station or loading area) be investigated in lieu of the barrier-free POP system. Off-board barrier-enforced fare payment involves turnstiles, fare gates, and ticket agents or some combination of all three in an enclosed station area or BRT vehicle station platform. It may involve entry control only or entry and exit control (particularly for distance-based fares). No matter which off-board fare payment system utilized, it is recommended that queuing at the front door to pay fares be eliminated to substantially reduce dwell times. This simple measure will aide in improving overall BRT vehicle average speeds. In conjunction with off-board fare payment, the fine for fare evasion needs to be considerable. This will send the message to customers that fare evasion will not be tolerated.

4.1.4.2 Passenger Information Systems

To the degree possible, it is recommended that BRT stations make use of ITS technology. At a minimum, this should include dynamic information displays prominently on view at stations showing the "approximate" time until next BRT vehicle arrival. Provision of additional information about BRT vehicle schedules will require techniques to predict the vehicle arrival time and the ability to display this information at stations. Providing next vehicle arrival time and other important travel information to BRT customers can be done also via mobile devices (e.g., PDA, cell phone) and supporting trip itinerary planning is possible with current technology and typically will require costly implementation across the entire transit network.

Providing customers with this information improves their overall satisfaction by helping to reduce wait-time anxiety and ultimately increases ridership by providing an improved customer experience. Passenger information systems can also be a source of transit system revenue through the sale of advertising time and space on dynamic information displays.

4.1.5 Operation and Service Plan

4.1.5.1 Reduction of Station Dwell Time

The most desirable features to include in the MDC BRT program are those that will provide the greatest improvements in speed, schedule reliability, and customer convenience with minimal cost. One of the most effective means of achieving the speed and schedule reliability associated with BRT involves minimizing dwell time at stations. There are several approaches to minimizing dwell time including minimizing the number of stops, the boarding time required by each customer, and the boarding time associated with wheelchair users and others with mobility impairments. Increasing the speed of the BRT vehicle relative to traffic also reduces travel time and improves schedule reliability, but techniques such a constructing designated runningway for achieving this will cost considerably more to implement.

4.1.5.2 Limited-Stop Service

It is recommended that a network of widely-spaced limited stops be implemented that are no less than 0.5-0.6 miles apart along any of the 11 proposed BRT corridors. This strategy will provide the opportunity for resources to be concentrated on the construction of high-quality customer stations at key intersections, major activity centers, and intermodal interchanges and will improve BRT vehicle speeds compared to local service.

4.1.6 Distinctive System Branding & Marketing

It is recommended that highly recognizable and appealing physical facilities (stations and even runningway), signage, and vehicle graphics be used to raise the visibility of the overall BRT system. This is an important objective for the BRT system since it establishes an image and brand identity separate from MDT local bus operations. This system branding will assist in attracting additional riders (particularly choice riders with other options) who may not want to use the current MDT local service for a variety of reasons. It is recommended that a coordinated and innovative graphics design initiative be developed and integrated with countywide transit marketing activities. For example, the bright red color-coded Metro Rapid vehicles in Los Angeles in conjunction with color-coordinated station graphics give the LA BRT system its unique brand and identity separate from MTA local services. Vehicle graphics, signage, schedules, web site, marketing information, and other printed materials should be coordinated to exhibit a cohesive look and feel to customers.

5. Next Steps

As was made clear by the literature review and the operational experiences of worldwide BRT systems, it makes the most sense to apply certain BRT elements only to particular corridors. Essentially, there is no one-size-fits-all approach to BRT. As a result, a common-sense approach to the application of the major elements was followed by balancing BRT system performance against cost. Many BRT systems have achieved great success (increased ridership that exceeded expectations) using only a few of the major BRT elements including ITS and a simple service and operation plan with limited capital funding (as low as $250,000 per mile for the Metro Rapid in Los Angeles). This evidence suggests a strong correlation between the BRT elements which are ultimately selected, system performance, and system benefits in specific corridors.

There are at least four important lessons that can be applied to MDC from the Metro Rapid in Los Angeles, they are:

- Providing better service, even along a local bus route, can increase ridership. Metro Rapid was designed to be faster, cleaner, and easier to use than the local buses running along the same corridors, and the traveling public took notice with 14 percent of Metro Rapid ridership being “net new” to public transit.
- Providing better service can be implemented inexpensively. Metro Rapid increased transit ridership in the Wilshire-Whittier Corridor by building a rapid bus-based transit system for a fraction of what light or heavy rail would cost. The service improvements did not have to be drastic to entice new riders, they just had to provide a similar and positive riding experience.
- Incremental adaptation can provide immediate results and allow new technology to be leveraged. LAMTA was able to deliver better service to its customers within nine months with the Metro Rapid, which resulted in an immediate improvement in the public perception of LAMTA services, and increased support for additional Metro Rapid projects and improvements. As a result, Metro Rapid expansion will consist of two new routes implemented every 6 months until June 2008 for a total of 480 miles of rapid bus service.
- Providing better bus-based service is something LAMTA should have been doing for its customers long before the implementation of the Metro Rapid. Local bus and Metro Rapid cost customers the same to ride.

Based on site visits to each of the 11 proposed BRT corridors, it is envisioned that the BRT routes will operate over a combination of runningways including arterial streets, designated curbside and median bus-only runningway on arterials streets, and potentially some type dedicated BRT vehicle-only runningway. For example, there are certain segments of Biscayne Boulevard just north of Downtown Miami where arterial street lanes are available that would allow for the implementation of designated curbside bus-only lanes. This runningway treatment, in conjunction with the prohibition and enforcement of on-street curbside parking during in-bound and out-bound peak hours (6 am to 9 am and 4 pm to 7 pm, for example), and TSP will improve BRT vehicle travel time and service reliability.

The MDC BRT program will include several key elements that will improve the service characteristics and customer experience over existing MDT local and express (MAX) services. These key elements should be implemented while maintaining "reasonable" capital and maintenance costs. These features include:

- Special runningway and queue jumper lanes dedicated to BRT along most of the corridor within right-of-way and funding constraints. Dedicated bus-only lanes are ideal, however, they will not always be politically or financially prudent/feasible
- TSP and signal coordination throughout the corridor
- Frequent all-day BRT service (5 to 12 minutes between BRT vehicles) with local service overlay
- Headway-based schedule which focus on maintaining rather than meeting specific schedule time points
- Wide BRT station spacing (0.5 miles between BRT stations, at a minimum)
- Visually appealing enhanced and/or designated BRT stations including shelters, boarding platforms, benches, security features, validation and ticket vending machines, real-time vehicle arrival information, and other amenities. Station design and area around stations should emphasize uniqueness of BRT service
- Proof-of-payment (POP) ticket validation at all or major stations

- Near-level or level boarding at stations
- Branding and marketing of the BRT system as a new, unique, and premium transit service
- Low-floor and low-emission BRT vehicles

Technical Memorandum Three (3) – BRT System Opportunities will recommend a common-sense combination of the major BRT elements for each proposed BRT corridor identified as part of the countywide MDC BRT program. Tech Memo Three (3) will include a detailed series of aerial maps showing approximate one-mile roadway segments from start to end for each of the proposed 11 BRT corridors in MDC. Each set of corridor maps will illustrate the route alignment, population density, employment density, and land uses. The data to create these maps were obtained from the 2000 US Census. Each one-mile segment will list the BRT elements, if any, most applicable to that particular one-mile roadway segment. For each of the proposed BRT corridors, ranges will be estimated for cost per route mile and total cost for the corridor, system performance, and system benefits based on the combination of BRT elements recommended. This is an important step since the choice of BRT elements ultimately determines overall BRT system performance. Performance characteristics, together with individual BRT elements, directly steer how benefits are generated. This relationship is shown in Exhibit 2.

EXHIBIT 2: Major BRT Elements – System Performance - System Benefits

Major Elements of BRT		System Performance		System Benefits
• Runningways • Stations • Vehicles • Fare Collection • ITS • Service and Operations Plan	⇨	• Travel Time Savings • Reliability • Safety & Security • Capacity • Identity and Image	⇨	• Ridership • Transit – Supportive Land Development • Capital Cost Effectiveness • Operating Efficiency • Environmental Quality • Land Development

This page intentionally left blank.

Appendix A – Technical Memorandum One (1)

This page intentionally left blank.

Overview of Bus Rapid Transit Opportunities as Part of an Integrated Multi-Modal Strategy to Alleviate Traffic Congestion in Miami-Dade County

Technical Memorandum One (1): Bus Rapid Transit Corridor Selection

Methodology and Results

Prepared for:

Miami-Dade Metropolitan Planning Organization

Prepared by:

Center for Urban Transportation Research
National Bus Rapid Transit Institute
College of Engineering, University of South Florida
4202 E. Fowler Avenue CUT 100
Tampa, Florida 33620-5375

Final Technical Memorandum One (1) – December 2004

This page intentionally left blank.

Table of Contents

Introduction 57

Methodology........ **Error! Bookmark n**

Identify Potential Candidate BRT Corridors........ **Error! Bookmark no**

Selection of BRT Corridors: Data, Approach, and Corridor Ranking........ 59
Data Sources........ 59
Approach........ 60
Ranking........ 62
Other Corridors for Additional Study........ 62

Next Steps........ 64

List of Exhibits

EXHIBIT 1: Potential BRT Corridors in Miami-Dade County 59

EXHIBIT 2: ..Candidate Bus Rapid Transit Corridors for Miami-Dade County 61

EXHIBIT 3: Rank Scores of Candidate Bus Rapid Transit Corridors for Miami-Dade County 62

EXHIBIT 4: ..Rank Scores of Expressway and Tollway Corridors for Miami-Dade County........ 63

This page intentionally left blank.

Introduction

The project "Overview of Bus Rapid Transit Opportunities as Part of an Integrated Multi-Modal Strategy to Alleviate Traffic Congestion in Miami-Dade County" complements, not duplicates, the Rapid Transit Expansion component of the *People's Transportation Plan* (PTP) that calls for rapid transit expansion in a number of corridors in Miami-Dade County (MDC). This project examines the feasibility of establishing some elements of Bus Rapid Transit (BRT) in relatively quick fashion in the corridors noted in the *PTP* as well as numerous others. While some of these corridors might ultimately accommodate rapid rail further off in the future, it is still important to determine if it is possible to have some form of faster bus-based transit service in place prior to the time that rail is made available. This project identifies other existing arterials that could accommodate BRT treatments that can be implemented relatively quickly and inexpensively, that deserve more careful review in future studies. The project objective is to identify arterials in MDC where relatively low-cost BRT treatments can give Miami-Dade Transit (MDT) buses competitive advantages as they provide new and more frequent service, and to identify the most feasible types of BRT improvements that can be made in the shortest timeframe to improve mobility options and speed of travel.

To date, there has been some work on analyzing the prospects for implementing BRT improvements on existing arterials in MDC. Initial analysis has been done on the NW 27th Avenue and North Kendall Drive corridors. Of course, the South-Miami Dade Busway running parallel to US 1 already provides a successful form of BRT. The *Program of Projects* completed in 1993 identified the Northeast Corridor as a good candidate for BRT. What is needed now are specific recommendations on possible corridors and the types of BRT improvements that can be made in a relatively short time frame that can be operational many years before rail projects may be completed, and in a fashion that is economically sound to provide better options for MDC commuters. The introduction of a new, high-quality mode of transit that offers faster travel choices for bus riders, especially the transit-dependent is an integral part of the *PTP.*

Methodology

For Technical Memorandum One (1), a simple indexing-based process was used to rank and select potential BRT corridors in MDC. To maintain or otherwise improve service levels consistent with rapid transit service, BRT examples in other cities indicate first that a critical threshold of riders per mile must be met to justify further BRT study and implementation as well as determine the potential for transit usage within individual corridors. These were strong considerations when deciding which corridors in MDC to advance for further study.

The BRT corridor selection process involved three simple steps:

Step 1: Identify a list of the potential candidate BRT corridors
Step 2: Refine and evaluate candidate BRT corridors
Step 3: Recommend candidate corridors for detailed analysis using a simple indexing based methodology

Identify Potential Candidate BRT Corridors

The *PTP* identifies rapid transit expansion in a number of specified corridors in MDC. *PTP* corridors are based on various levels of analysis during the last decade coupled with extensive public involvement. Based on this and thorough input from Miami-Dade Metropolitan Planning Organization (MPO) and MDT staff, a number of candidate BRT corridors were selected for initial refinement. These corridors represent those with the highest current concentration of MDT bus service and ridership as well as meeting the needs of the entire MDT transit system network in terms of connectivity, geographic east-west and north-south coverage, and potential success in terms of increased system and future corridor ridership resulting from forecasted growth and traffic congestion mitigation. Based on direction provided by the MPO, three additional expressway and tollway facilities were included as part of the corridor selection process. The potential BRT corridors are shown in Exhibit 1.

EXHIBIT 1: Potential BRT Corridors in Miami-Dade County

A	B	C	D	E
Proposed BRT Corridor	**From**	**To**	**Candidate BRT Corridor Route Mileage /1**	**Rapid Transit Priority Status /2**
Flagler Street	FL Turnpike	Government Center	12.37	Very High (*PTP* Corridor)
US 1 – Biscayne Boulevard	Aventura Mall	Downtown Miami	13.4	Very High (*PTP* Corridor)
LeJeune Road	Gratigny Parkway	Douglas Road Metrorail Station	10.93	Very High (*PTP* Corridor)
Kendall Drive	SW 147th Avenue	Dadeland South	7.07	Very High (*PTP* Corridor)
NW 79th Street	NW 87th Avenue	Miami Beach	10.86	High
NW 7th Avenue	Golden Glades	Downtown Miami	7.83	High
Coral Way	FL Turnpike	Brickell Metrorail Station	10.54	High
W 49th Street	W 16th Avenue	NW 27th Avenue	5.3	High
SW 87th Avenue	Dadeland South Metrorail Station	Palmetto Metrorail Station	11.27	High
SW 107th Avenue	Eureka Drive (184th Street)	Palmetto Metrorail Station	16.53	High
SW 137th Avenue	South Miami-Dade Busway	Flagler Street	16.07	High
SW 152nd Street	South Miami-Dade Busway	SW 162nd Avenue	7.16	Medium
Miami Gardens Drive	NW 87th Avenue	US 1 – Biscayne Boulevard	12.36	Medium
SW 40th Street	SW 117th Avenue	Douglas Road Metrorail Station	9.1	Medium
NW 135th Street	NW 12th Avenue	US 1 – Biscayne Boulevard	10.26	Medium
Other Corridors for Additional Study /3				
SR 826 (Palmetto)	South Miami-Dade Busway	I-95	23.34	High
SR 836 (Dolphin)	I-95 (Downtown Miami)	FL Turnpike	11.66	High
Homestead Ext. FL Turnpike (HEFT)	South Miami-Dade Busway	Homestead/US-1	12.51	High

/1 Candidate BRT corridor route mileage calculated by CUTR GIS using ArcView software
/2 PTP stands for *People's Transportation Plan*
/3 Three corridors currently being evaluated for study as part of MPO's ongoing *Special-Use Lane Study*

Selection of BRT Corridors: Data, Approach, and Corridor Ranking

Data Sources

Key criteria were identified as influencing the success of BRT service in MDC and, in fact, any major transit investment. These criteria are:

- Current Transit Service – measures current corridor transit using average weekday ridership for the MDT bus routes currently serving the proposed BRT corridors.
- Corridor Transit Potential – measures transit potential using an index of current residential and employment density within a ½-mile walking distance of the possible

BRT corridors. In addition, future transit potential was considered for total population, total households, vehicles, workers, and employment for certain growth areas of MDC using mapped forecasted growth data from the MPO's 2030 Long-Range Plan.

- Corridor Transit Dependency – measures transit dependency using an index of percentage of households below poverty and percentage of households without vehicles.

Information for total average weekday rider boardings was obtained directly from MDT service planning from its *Omnibus* reporting system. The most recent data available from MDT was reported for October 2003. The ridership data reflect total average weekday boardings; data for weekend service was not included. Data for candidate BRT corridor length was calculated by CUTR's GIS department using ArcGIS 9.0 software. Recent employment and residential data were obtained from the 2000 US Census using a ½-mile buffer around each proposed BRT corridor, and data for future growth was obtained from the MPO. Transit dependency data included households with zero-auto ownership and households living in poverty. These data were obtained from the 2004 on-board survey performed by CUTR for MDT. Finally, data for future transit potential was obtained from maps provided as part of the MPO's 2030 Long-Range Plan. These maps show projected total growth for population, households, vehicles, workers, and employment out to the year 2030. The maps used were dated March 30, 2004 and were provided to CUTR by the MPO for use in this technical memorandum.

Approach

The final evaluation process resulted in the ranking of the candidate BRT corridors. The challenge in selecting corridors for any rapid transit mode is to balance the individual ridership thresholds with other factors and the needs of the entire network in terms of connectivity, achieving geographic east-west and north-south coverage, potential success of the new rapid mode, and the need for transit service considering issues such as duplication and competition for the same markets as existing bus/rail service as well as saturating one part of the transit system's service area.

Given this, each of the potential BRT corridors was evaluated based on an indexing methodology that ranked current corridor transit usage, corridor transit potential, and corridor transit dependency. All else being equal, those proposed BRT corridors with the highest overall transit potential scores represent the best candidates for BRT improvements in the near-term.

The evaluation of the proposed BRT corridors consisted of analyzing transit usage, transit potential, and transit dependence variables using an indexed- and ranked-scoring process. This scoring process uses a "percentage of the best" approach, whereby the top scoring corridor in each criterion received "100 percent," with the other proposed corridors receiving scores relative to the top score. For example, if the US-1/Biscayne Boulevard corridor percentage of zero-auto household ownership was the top score with 40 percent, it would receive an index score of 100 and Flagler Street's corridor percentage for the

EXHIBIT 2: Candidate Bus Rapid Transit Corridors for Miami-Dade County

A	B	C	D	E	F	G	H	I
Proposed BRT Corridor	**Route Numbers for MDT Routes that Operate on all or a Portion of Candidate BRT Corridors**	**Total Average Weekday Boardings /1**	**Candidate BRT Corridor Route Mileage /2**	**Riders per Mile of Candidate BRT Corridor Length**	**Residential + Employment within 1/2-Mile Buffer of Corridor /4**	**Residential + Employment per Mile of Candidate BRT Corridor Length**	**Zero Auto Ownership /3**	**Annual Household Incomes Less than $15k per Year /3**
NW 79th Street	107 (G), 112 (L)	13,542	10.86	1,248	135,133	12,443	50.3%	58.3%
Flagler Street	11, 51	15,353	12.37	1,241	156,608	12,660	46.8%	62.2%
NW 7th Avenue	77	10,975	7.83	1,402	129,862	16,585	40.4%	59.1%
US 1 – Biscayne Blvd	3, 16, 93	15,770	13.4	1,177	127,147	9,489	47.1%	56.6%
SW 152nd Street	35, 52, 252	6,013	7.16	840	31,245	4,364	43.8%	59.1%
Coral Way	Coral Way MAX (224), 24	4,344	10.54	412	140,088	13,291	44.2%	68.2%
Miami Gardens Drive	75, 83	8,677	12.36	702	142,773	11,551	31.5%	59.0%
LeJeune Road	42, 110 (J)	6,096	10.93	558	123,976	11,343	38.9%	45.7%
SW 40th Street	40, 240	2,805	9.1	308	108,735	11,949	40.1%	54.1%
W 49th Street	33	2,344	5.3	442	94,057	17,747	31.7%	57.5%
Kendall Drive	88, 104, 288	4,845	7.07	685	97,199	13,748	29.8%	44.0%
NW 135th Street	28, 105 (E)	2,470	10.26	241	109,078	10,631	33.5%	53.0%
SW 87th Avenue	87	2,031	11.27	180	91,928	8,157	34.4%	51.8%
SW 107th Avenue	71	1,507	16.53	91	158,028	9,560	28.6%	54.3%
SW 137th Avenue	West Dade Connection (137)	1,150	16.07	72	76,285	4,748	32.4%	60.8%

/1 Metro-Dade Transit *Omnibus* ridership report dated October 2003.
/2 Candidate BRT corridor route mileage calculated by CUTR GIS using ArcView software.
/3 Obtained from recent on-board survey of Miami-Dade Transit bus system conducted by CUTR. These data represent actual ridership characteristics for each existing MDT bus route listed in Column B.
/4 Data obtained from the 2000 US Census.

same factor was 30 percent, it would receive a score of 75 and so on for each of the other potential BRT corridors in the analysis. An overall transit potential score was determined by averaging the scores across the four criteria. The results are presented in Exhibit 2 and Exhibit 3.

Ranking

The implementation of BRT service in MDC has been prioritized into two tiers following the recommended rapid transit expansion schedule from the *PTP* for years 2003 to 2025. Tier I BRT corridor implementation is for years 2005 through 2010 and Tier II are for 2011 to 2025. It is anticipated that Tier I represents the highest priority corridors for BRT service. Depending on the costs associated with the necessary improvements, it is possible that BRT implementation could occur more quickly than the schedule suggested in Exhibit 3.

EXHIBIT 3: Rank Scores of Candidate Bus Rapid Transit Corridors for Miami-Dade County

A	B	C	D	E	F	G	H
Proposed BRT Corridor (Rank Order Based on Overall Transit Potential Score in Column F)	**Riders per Mile Score**	**Residential + Employment Score**	**Household Zero-Auto Ownership Score**	**Household Income Poverty Score**	**Overall Transit Potential Score /1**	**Implement Timeframe**	**Tier Inclusion**
Flagler Street	88.5	99.1	93.0	91.2	92.97	2005 to 2010	I
NW 79th Street	89.0	85.5	100.0	85.5	90.00	2005 to 2010	I
NW 7th Avenue	100.0	82.2	80.3	86.7	87.29	2005 to 2010	I
US 1 – Biscayne Boulevard	84.0	80.5	93.6	83.0	85.26	2005 to 2010	I
Coral Way	29.4	88.6	87.9	100.0	76.48	2005 to 2010	I
Miami Gardens Drive	50.1	90.3	62.6	86.5	72.39	2011 to 2030	II
LeJeune Road	39.8	78.5	77.3	67.0	65.65	2005 to 2010	I
SW 152nd Street	59.9	19.8	87.1	86.7	63.36	2011 to 2030	II
SW 40th Street	22.0	68.8	79.7	79.3	62.46	2011 to 2030	II
SW 107th Avenue	6.5	100.0	56.9	79.6	60.74	2005 to 2010	I
W 49th Street	31.5	59.5	63.0	84.3	59.59	2005 to 2010	I
Kendall Drive	48.9	61.5	59.2	64.5	58.53	2005 to 2010	I
NW 135th Street	17.2	69.0	66.6	77.7	57.63	2011 to 2030	II
SW 87th Avenue	12.8	58.2	68.4	76.0	53.84	2005 to 2010	I
SW 137th Avenue	5.1	48.3	64.4	89.1	51.74	2005 to 2010	I

/1 Average of Columns B through E

Other Corridors for Additional Study

Additionally, MPO staff has requested that the universe of potential BRT corridors be expanded for this project to include the following expressway and tollway facilities in MDC for BRT special-use lane treatment: SR 826 (Palmetto) and SR 836 (Dolphin) expressways and the Homestead Extension of the Florida Turnpike (HEFL). Exhibit 4 shows the overall transit potential score determined by averaging the score for the transit potential (residential + employment density) for the three facilities. There are currently no MDT bus services operating on these three facilities.

SR 836 has been the subject of intensive study for the application of special-use lanes such as an exclusive BRT travel way. To date, no special-use lanes have been implemented on SR 836 and there currently is no MDT bus service operating on it. Based on the results shown in Exhibit 4, SR 836 is the strongest candidate for any new special-use lanes to accommodate future BRT service. An east-west special-use lane for BRT service on SR 836 could provide additional intra-county mobility and transportation options.

EXHIBIT 4: Rank Scores of Expressway and Tollway Corridors for Miami-Dade County

A	B	C	D	E	F	G
Proposed BRT Corridor	**Riders per Mile Score /1**	**Residential + Employment Score /3**	**Household Zero-Auto Ownership Score /2**	**Household Income Poverty Score /2**	**Overall Transit Potential Score /4**	**Rank Order Based on Overall Transit Potential Score**
Dolphin Expressway (SR 836)	NA	100.0	NA	NA	100.0	1
Palmetto Expressway (SR 826)	NA	69.2	NA	NA	69.2	2
Florida Turnpike Homestead Extension	NA	34.4	NA	NA	34.4	3

/1 Data not available from the Metro-Dade Transit Omnibus ridership report dated October 2003; no MDT bus service currently operating on these facilities.
/2 Data not available from recent on-board survey of Miami-Dade Transit bus system conducted by CUTR; no MDT bus service currently operating on these facilities.
/3 Data obtained from the 2000 US Census.
/4 Average of Column C.

The Miami-Dade County MPO is currently sponsoring a *Special-Use Lane Study* to investigate the creation of special-use lanes to enhance mobility and travel options across MDC. The MPO feels that the creation of a linked system of special-use lanes could lead to stronger utilization of arterials such as Flagler Street and freeways such as the Palmetto

Expressway. The *Special-Use Lane Study* is proposing an interconnected system that includes, as mentioned, facilities both on freeways and on arterials. While the *Special-Use Lane Study* makes reference to the feasibility of BRT in freeway and arterial corridors, it refrains from making specific recommendations about actual BRT facilities; this study is charged with that task.

Next Steps

As shown in Exhibit 3, there are 11 corridors included as part of Tier I BRT corridors. These corridors should receive highest priority for further analysis and implementation of some type and configuration of BRT service during the recommended implementation timeframe. For example, the high priority rapid transit *PTP* corridors of Flagler Street and Biscayne Boulevard could be implemented in the near term as possible BRT demonstration project(s).

Based on the results shown in Exhibit 3, CUTR will study further the top 11 candidate BRT corridors listed in Tier I as part of the "Overview of Bus Rapid Transit Opportunities as Part of an Integrated Multi-Modal Strategy to Alleviate Traffic Congestion in Miami-Dade County" project. The top ranking corridors are those where BRT treatments such as transit signal priority and wider stop spacing can give MDT buses competitive advantages as they provide new and more frequent rapid bus service throughout MDC.

Due to data limitations, the results in Exhibits 2 and 3 look only at current conditions in MDC and not conditions over a long-term horizon. Of course, total population and other factors will <u>not</u> remain constant in the future. Between 2000 and 2030, the MPO estimates that in MDC population will increase by 43 percent, housing by 40 percent, employment by 34 percent, number of automobiles by 48 percent, and person-trips by 40 percent when compared to current levels. Along with this growth, increasing demands will be placed on the public transit system. Meeting future transportation needs is made even more complex by the multi-directional nature of daily travel throughout MDC. The predominant suburb-to-downtown commute pattern that many large cities experience does not exist as prominently in MDC. While Downtown Miami remains a major trip attractor, people commute from everywhere to everywhere in MDC. While this means that demand is spread throughout the system rather than concentrated in a few corridors, it also means that improvements, and therefore additional resources, are needed throughout including the rapidly growing southwest portion of MDC. Population and other transit-oriented trends developed by the MPO indicate that rapid growth is occurring in the southwest portion of MDC; in fact it is one of the fastest growing areas of the county. Based on this, it was decided that SW 152nd Avenue, SW 137th Avenue, and SW 107th Avenue should be included as Tier I BRT corridors. While the original corridor selection process ranked these three corridors low, this is attributable to their current levels of public transit service (one hour headways vs. 10 minute headways, which have a significant negative effect on current ridership). Due to the rapid growth in this area of MDC, it is anticipated the level of public transit service and ridership will more closely mirror that of one of the more mature, higher ranked corridors shown in Exhibit 3 in the future. These corridors will be subject to more detailed analysis and evaluation in Technical Memorandum Three (3) of this study.

This page intentionally left blank.

Appendix B – List of Transit Terminology

This page intentionally left blank.

Glossary of Public Transit Terminology

Accessibility extent to which facilities are barrier free and useable by persons with disabilities, including wheelchair users and families using baby carriages.

Accessible Station a station which provides ready access, and does not have physical barriers that prohibit and/or restrict access by individuals with disabilities, including individuals who use wheelchairs.

Accessible Vehicle a public transportation revenue vehicle that does not restrict access, is usable, and provides allocated space and/or priority seating for individuals who use wheelchairs.

Active Transit Station Signs information system located at each facility to provide real-time travel information to passengers, including expected arrival time of next vehicle, unusual delay, etc.

Active Vehicle a vehicle in the year end fleet that is available to operate in revenue service, including spares and vehicles temporarily out of service for routine maintenance and minor repairs.

Alighting the act of getting off of a public transit vehicle.

Alternative Fuels low-polluting fuels which are used to propel a vehicle instead of high-sulfur diesel or gasoline. Examples include methanol, ethanol, propane or compressed natural gas, liquid natural gas, low-sulfur or "clean" diesel and electricity.

Arterial Street a major thoroughfare, used primarily for through traffic rather than for access to adjacent land, that is characterized by high vehicular capacity and continuity of movement.

Articulated Bus a bus usually 55 feet or more in length with two connected passenger compartments that bend at the connecting point when the bus turns a corner.

Auto Restricted Zone (ARZ) an area in which normal automobile traffic is prohibited or limited to certain times, and vehicular traffic is restricted to public transit, emergency vehicles, taxicabs and, in some cases, delivery of goods.

Automated Guideway an electric railway operating without vehicle operators or other crew on board the vehicle.

Automatic Fare Collection System (AFC) a system of controls and equipment that automatically admits passengers on insertion of the correct fare in coins, tokens, tickets or farecards; it may include special equipment for transporting and counting revenues.

Automatic Vehicle Location System (AVLS) technology that tracks the current location of fleet vehicles to assist in dispatching, maintaining schedules, answering specific customer inquiries, etc.

Auto-Oriented Development development that is designed with an emphasis on access and parking by personal vehicles. This type of development is characterized by large surface parking lots, wide streets, few or no sidewalks and long distances between buildings

Availability the proportion of the public passenger vehicle fleet which is available to be used in Service.

Average Speed vehicle revenue miles divided by vehicle revenue hours.

Barrier Fare Collection a fare payment system consisting of a secure facility to which a passenger is only allowed access upon fare payment

Base Fare the price charged to one adult for one transit ride; excludes transfer charges, zone charges, express service charges, peak period surcharges and reduced fares

Base Period the period between the morning and evening peak periods when transit service is generally scheduled on a constant interval. Also referred to as the "off-peak period."

Bi-articulated Bus a bus usually 75 feet or more in length with three connected passenger compartments that bend at the connecting point when the bus turns a corner. Bi-articulated buses have a seated and standing capacity of approximately 240 passengers

Boarding the act of getting on to a public transit vehicle.

Breakdown a mechanical defect which immobilizes a vehicle.

BRT Stop any on-street BRT station location serving a single BRT route

BRT Superstop any on-street designated BRT station location at which point two BRT routes intersect and allow for transfers

Bunching the act of buses catching up with one another so that several run together, followed by a long interval before the next bus. Also known as platooning

Bus a rubber-tired, self-propelled, manually-steered vehicle with fuel supply carried on board the vehicle. Types include advanced design, articulated, bi-articulated, circulator, double deck, express, feeder, intercity, medium-size, small, standard-size, subscription, transit and van

Bus Lane a street or highway lane intended primarily for buses, either all day or during specified periods, but sometimes also used by carpools meeting requirements set out in traffic laws

Bus Mile Equivalents the number of vehicle miles that would have been operated by a transit mode if the service had been provided by buses. Based on average seating plus standing capacity of the vehicle as compared to the capacity including standees (70 people) of a standard-size bus.

Bus Mode a transit mode using vehicles powered by diesel, gasoline, battery or alternative fuel engines contained within the vehicle.

Bus Rapid Transit (BRT) a combination of technologies, design features, operating practices, and marketing approaches that allow rubber-tired transit vehicles to approach the speed and service quality of rail transit service

Bus Shelter a building or other structure constructed near a bus stop, to provide seating and protection from the weather for the convenience of waiting passengers

Bus Stop a place where passengers can board or alight from the bus, usually identified by a sign

Busway exclusive freeway lane for buses and carpools

Cannibalization the act of removing parts from one bus to use on another

Capital Costs costs of long-term assets of a public transit system such as property, buildings, vehicles, etc

Carpool an arrangement where two or more people share the use and cost of privately owned vehicles in traveling together to and from pre-arranged destinations. Carpools are not public transportation.

Catchment Area area from which primary transit ridership is drawn

Central Business District (CBD) the downtown retail trade and commercial area of a city or an area of very high land valuation, traffic flow, and concentration of retail business offices, theaters, hotels and services

Circulator Bus a bus serving an area confined to a specific locale, such as a downtown area or suburban neighborhood with connections to major traffic corridors

Closed Door Operation the prohibition of picking up and setting down passengers while operating a public transport vehicle along specified segments of a defined route

Community Transportation Center an off-road BRT facility which may serve as a terminal or point of transfer for one or several BRT and local service routes

Commuter a person who travels regularly between home and work or school

Compressed Natural Gas (CNG) an alternative fuel; compressed natural gas stored under high pressure. CNG vapor is lighter than ai

Contraflow Lane reserved lane for buses on which the direction of bus traffic is opposite to the flow of traffic on the other lanes

Controlled Access Right-of-Way--Lanes right-of-way restricted for at least a portion of the day for use by transit vehicles and/or other high occupancy vehicles. Use of controlled access lanes may also be permitted for vehicles preparing to turn. The restriction must be sufficiently enforced so that 95 percent of vehicles using the lanes during the restricted period are authorized to use them.

Corridor a broad geographical band that follows a general directional flow connecting major sources of trips that may contain a number of streets, highways and transit route alignments

Crew the bus driver, train driver and conductor assigned to a bus or train

Crosstown non-radial bus or rail service which does not enter the Central Business District (CBD)

Cutaway Van a standard van that has undergone some structural changes, usually made to increase its size and particularly its height. The seating capacity of a cutaway van is approximately nine to 18 passengers

Dead Mileage the mileage (or kilometers) operated by buses not in revenue-earning service, most commonly between the depot and the point at which the bus takes up its route

Deadhead the movement of a transit vehicle without passengers aboard; often to and from a garage or to and from one route to another

Dedicated Funding Source a source of monies which by law is available for use only to support a specific purpose, and cannot be diverted to other uses

Demand Responsive non-fixed-route service utilizing vans or buses with passengers boarding and alighting at pre-arranged times at any location within the system's service area. Also called "Dial-a-Ride." Also, comparable transportation service for individuals with disabilities who are unable to use fixed-route transportation systems

Depreciation a non-cash expense recognizing the cost of a capital asset distributed over the economic life of the asset

Destination the point at which a journey or trip ends

Dial-a-Ride see "Demand Responsive."

Directional Route Miles the mileage in each direction, over which public transportation vehicles travel while in revenue service. Directional route miles are a measure of the route path over a facility or roadway, not the service carried on the facility; e.g. number of routes, vehicles or vehicle revenue miles. Directional route miles are computed with regard to direction of service, but without regard to the number of traffic lanes or rail tracks existing in the right-of-way. Directional route miles do not include staging or storage areas at the beginning or end of a route.

Double decked bus a high-capacity bus having two levels of seating, one over the other, connected by one or more stairways. Total bus height is usually 13 to 14.5 feet, and typical passenger seating capacity ranges from 40 to 80 people. Although common in older cities of Europe and Asia where street capacity is very limited, only a handful of such buses are used in U.S. transit service.

Down Time the period of time when a bus is not available for service due to maintenance or Repair

Driver a person who acts as steersman or motorman of a public passenger vehicle in public transport service

Dual-mode trolleybus a trolleybus that has an on-board power source that can be used in emergencies or to extend the route beyond the end of the overhead wires. Only one city (Seattle) operates such vehicles.

Dwell Time the scheduled time a vehicle or train is allowed to discharge and take on passengers at a stop, including opening and closing doors

Early Shift a crew duty starting in the early morning and finishing around mid-day

Electric Trolley Bus (ETB) an electric, rubber-tired transit vehicle, manually steered, propelled by a motor drawing current through overhead wires from a central power source not on board the vehicle. Also known as "trolley coach" or "trackless trolley."

Elevated a fixed guideway built on bridge or other aerial support structures with stations located above grade

Exclusive Right-of-Way a highway or other facility that can only be used by buses or other transit vehicles

Express Bus a bus that operates a portion of the route without stops or with a limited number of stops. The express bus service is scheduled to operate faster than local service by limiting the number of stops the bus will make along the route

Fare the approved sums payable in respect of a contract ticket for an individual passenger's Transport

Fare Box Recovery Ratio measure of the proportion of operating expenses covered by passenger fares; found by dividing fare box revenue by total operating expenses for each mode and/or systemwide

Fare Box Revenue value of cash, tickets, tokens and pass receipts given by passengers for transport services provided by the Operator as payment for rides; excludes charter revenue and revenue from advertising and concessions

Fare Elasticity the extent to which ridership responds to fare increases or decreases

Fare Evasion unlawful use of transit facilities by riding without paying the applicable fare

Fare Structure the system set up to determine how much is to be paid by various passengers using a transit vehicle at any given time

Feeder Bus a bus service that picks up and delivers passengers to a rail rapid transit station or express bus stop or terminal

"First Mile"/"Last Mile" the often unserved or neglected gap a transit user may experience between the closest point of transit access and the ultimate origin or terminus of a trip

Fixed Cost an indirect cost that remains relatively constant, irrespective of the level of operational activity

Fixed Guideway System a system of vehicles that can operate only on its own guideway constructed for that purpose (e.g., rapid rail, light rail). Federal usage in funding legislation also includes exclusive right-of-way bus operations, trolley coaches and ferryboats as "fixed guideway" transit

Fixed Route service provided on a repetitive, fixed-schedule basis along a specific route with vehicles stopping to pick up and deliver passengers to specific locations; each fixed-route trip serves the same origins and destinations

Fleet Number an identification number assigned to a bus by its Operator

Flex-Route Bus Service local bus service which is not operated on a specific fixed guideway, but instead serves an area by diverting onto a local street network

Force Majeure a disruptive event or effect that cannot be reasonably anticipated or controlled as in acts of war and civil strife, work stoppages resulting from labor disputes, or acts of terrorism but not acts of a diety

Frequency the interval in minutes between buses operating on a route, or the number of buses per hour

Fringe Parking an area for parking usually located outside the Central Business District (CBD) and most often used by suburban residents who work or shop downtown

Headway time interval between vehicles moving in the same direction on a particular route

High-floor vehicle a vehicle that requires riders to climb 2 or 3 steps from street level. Such vehicles accommodate wheelchair-bound and other riders who cannot climb steps by using a retractable lift (usually formed from the vehicle's steps) that raises and lowers persons and equipment between street and floor levels.

High Occupancy Vehicle (HOV) vehicles that can carry two or more persons. Examples of high occupancy vehicles are a bus, vanpool and carpool. These vehicles sometimes have exclusive traffic lanes called "HOV lanes," "busways," "transitways" or "commuter lanes."

High-Occupancy Vehicle (HOV) Facility (Commuter Lane or Transitway) Exclusive or controlled access right-of-way that is restricted to high occupancy vehicles (buses, passenger vans and cars carrying one or more passengers) for a portion or all of a day.

Illegal Operator the person or organization to whom no license has been granted or issued or a license holder operating a public passenger vehicle outside the licensed area

Infill Development in land-use and transit planning, development of vacant parcels in urbanized or suburbanized areas

Intelligent Transportation System (ITS) automated systems of highway transportation designed to improve traffic monitoring and management. ITS includes: Advanced Public Transportation Systems (APTS), Automatic Vehicle Location System (AVLS) and "smart vehicles" which assist drivers with planning, perception, analysis and decision-making

Intercity Bus a bus with front doors only, high-backed seats, separate luggage compartments, and usually with restroom facilities for use in high-speed long-distance service

Intermodal those issues or activities which involve or affect more than one mode of transportation, including transportation connections, choices, cooperation and coordination of various modes. Also known as "multimodal."

Involuntary Stop the stoppage of a bus caused by a breakdown

Jitney a transit mode comprised of passenger cars or vans operating on fixed routes (sometimes with minor deviations) as demand warrants without fixed schedules or fixed stops. There are currently no jitneys reported to the Federal Transit Administration's National Transit Database, though a number of unofficial and often illegal jitneys are known to exist.

Joint Development ventures undertaken by the public and private sectors for development of land around transit stations or stops

Kiss and Ride (K&R) a place where commuters are driven and dropped off at a station to board a public transportation vehicle

Late Shift a crew duty starting in the afternoon and finishing in the evening

Layover the waiting time at the terminus between trips

Layover Time time built into a schedule between arrival at the end of a route and the departure for the return trip, used for the recovery of delays and preparation for the return trip

Level Boarding a physical transit facility feature which provides a raised boarding platform to enhance the speed and accessibility of boarding and alighting passengers

Level of Service (LOS) a set of characteristics that indicate the quality and quantity of transportation service provided, including characteristics that are quantifiable and those that are difficult to quantify

Limited-stop Service a service which is scheduled not to stop at all stops on a route, and which normally operates to a reduced running time

Linked Trip a trip from origin to destination on the transit system regardless of the number of transfers a passenger must make during a journey. A complete one-way trip on the system

Liquefied Natural Gas (LNG) an alternative fuel; a natural gas cooled to below its boiling point of -260 degrees Fahrenheit so that it becomes a liquid; stored in a vacuum bottle-type container at very low temperatures and under moderate pressure. LNG vapor is lighter than air

Livery the color scheme and insignia applied to a bus or other public transport vehicle

Load Factor the ratio of passengers actually carried versus the total passenger capacity of a Vehicle

Local Service a bus service where vehicles may stop every block or two along a route several miles long, by far it is the most common type of bus service. Trolleybuses, unless bypass overhead wiring is available, cannot pass the trolleybus in front of them, and thus generally operate in local service only.

Low-floor Vehicle a vehicle that eliminates the steps at the front entrance and has a level floor in the front part of the vehicle. Only a short retractable ramp is necessary to accommodate wheelchairs and those who cannot bridge the gap between vehicle and street level. Some models have a level floor the entire length of the vehicle and no steps at the rear door.

Market Rate or Market Value the price agreeable to willing buyers and willing sellers

Mass Transit see "Public Transportation."

Mass Transportation see "Public Transportation."

Mean Distance Between Failures (MDBF) the average distance in miles that a transit vehicle travels before failure of a vital component forces removal of that vehicle from service

Medium-Size Bus a bus from 29 to 34 feet in length

Methanol an alternative fuel; a liquid alcohol fuel with vapor heavier than air; primarily produced from natural gas

Miles of Track the sum of the number of tracks per one mile segment of right-of-way. Miles of track are measured without regard to whether or not rail traffic can flow in only one direction on the track. All track is counted, including yard track and sidings.

Missed Trip a revenue trip not operated

Modal Split a term which describes how many people use alternative forms of transportation. Frequently used to describe the percentage of people using private automobiles as opposed to the percentage using public transportation

Mode types of transportation available for use, such as rail, bus, vanpool, personal vehicle or Bicycle

Model an analytical tool (often mathematical) used by transportation planners to assist in making forecasts of land use, economic activity, travel activity and their effects on the quality of resources such as land, air and water

Multimodal See “Intermodal”

National Transportation System an intermodal system consisting of all forms of transportation in a unified, interconnected manner to reduce energy consumption and air pollution while promoting economic development and supporting the nation's preeminent position in international commerce. The NTS includes the National Highway System (NHS), public transportation and access to ports and airports.

Neighborhood Trolley See “Circulator”

Next-Stop Annunciators on-board vehicle information system designed to inform passengers of upcoming stations and points of transfer

Non-fixed-route service services not provided on a repetitive, fixed-schedule basis along a specific route to specific locations. Demand response is the only non-fixed-route mode.

Off-Board Fare Payment a fare payment system intended to accelerate bus boarding by providing a fare validation mechanism at an off-vehicle location

Off-Peak Period non-rush periods of the day when travel activity is generally lower and less transit service is scheduled. Also called "base period."

On-time Performance the proportion of the time that a transit system adheres to its published schedule times within stated tolerances

Operating Deficit the sum of all operating expenses minus operating revenues

Operating Expense monies paid in salaries, wages, materials, supplies and equipment in order to maintain equipment and buildings, operate vehicles, rent equipment and facilities and settle claims. This does not include depreciation

Operating Profit the remainder of subtracting operating expenses from total revenue

Operating Revenue receipts derived from or for the operation of transit service, including fare box revenue, revenue from advertising, interest and charter bus service and operating assistance from governments

Operator the person or organization to whom a public transport license was granted and issued and who is providing a bus or rail service. This does mean “driver.”

Ordinary Fare the fare paid for stage carriage service by all passengers who are not Concessionaires

Overhaul the major maintenance work carried out on a vehicle or unit (such as an engine or gearbox), normally involving the removal and replacement of a large number of parts

Over-riding the traveling by a passenger further than the distance paid for

Paratransit informal transit services provided by operators who may or may not be licensed for public transport common carriage

Park and Ride designated parking areas for automobile drivers who then board transit vehicles from these locations

Passenger any occupant of a public transport vehicle (in or upon the vehicle) who is not the Driver

Passenger Vehicle a vehicle used to carry passengers in transit service.

Passenger Miles the total number of miles traveled by passengers on transit vehicles; determined by multiplying the number of unlinked passenger trips times the average length of their trips

Peak Period morning and afternoon time periods when transit riding is heaviest

Peak/Base Ratio the number of vehicles operated in passenger service during the peak period divided by the number operated during the base period

Point Deviation a type of transit service in which a vehicle stops at specified checkpoints (shopping centers, employment centers, etc.) at specified times, but travels a flexible route between these points to serve specific customer requests for doorstep pickup or delivery

Premium Fare the market rate fare paid for express bus or premium rail service

Premium Service a category of express bus or rail transit service that provides higher levels of comfort to passengers. These features may include air-conditioning, guaranteed seating or other comfort items and services

Preventative Maintenance the scheduled maintenance of vehicles to minimize the occurrence of mechanical failure, rather than only rectifying defects as they occur

Programmed Maintenance a planned maintenance program based on preventive maintenance principles and including other maintenance activities such as periodic repainting, chassis and body overhaul, etc

Proof-of-Payment Fare Collection a fare payment system in which a passenger pays the fare upon entry to the vehicle, and regulated by on-board personnel who may randomly check for proof of fare payment

Propane an alternative fuel; a liquid petroleum gas (LPG) which is stored under moderate pressure and with vapor heavier than air; produced as a by-product of natural gas and oil production

Publico a mode similar to jitney, which is comprised of passenger vans or small buses operating with fixed routes but no fixed schedules. Publicos are a privately owned and operated mass transit service which is market oriented and unsubsidized, but regulated through a public service commission, state, or local government. Publicos are operated under franchise agreements, fares are regulated by route, and there are special insurance requirements. Vehicle capacity varies from 8 to 24, and the vehicles may be owned or leased by the operator.

Public Passenger Vehicle any mechanically propelled vehicle intended or adapted for use on the roads or on rails to carry passengers for hire or reward

Public Transport System an organization that provides transport services owned, operated, or subsidized by any municipality, Emirate, regional authority, or other governmental agency, including those operated or managed by a private management firm under contract to the government agency owner

Public Transportation transportation by bus, rail, or other conveyance, either publicly or privately owned, which provides to the public general or special service on a regular and continuing basis. Also known as "mass transportation," "mass transit" and "transit."

Pull-in the arrival of buses or trains at the depot or yard at the end of the operating day

Pull-out the departure of buses or trains from the depot or yards at the start of the operating day

Queue Jumper Lane a near-side traffic lane, used in conjunction with *traffic signal priority* (see definition) which allows for transit vehicles to bypass queued automotive traffic and move through the intersection in order to maintain consistent headway operations and reduce trip delays due to traffic congestion

Rapid Transit rail or motorbus transit service operating completely separate from all modes of transportation on an exclusive right-of-way

Regional Transportation Center a major off-road BRT facility which may serve as a terminal or point of transfer for one or several BRT and local service routes, as well as providing additional operator and passenger amenities with design and service features to compliment local land uses

Rehabilitation the rebuilding of revenue vehicles to original specifications of the manufacturer. Rebuilding may include some new components but has less emphasis on structural restoration than would be the case in a remanufacturing operation, focusing on mechanical systems and vehicle interiors.

Revenue Service the time period when a public transport vehicle is available to the general public and there is a reasonable expectation of carrying passengers that either directly pays fares are assisted by public policy or provide payment through some contractual arrangement. Vehicles operated in fare-free service are considered to be in revenue service

Reverse Commuting movement in a direction opposite the main flow of traffic, such as from the central city to a suburb during the morning peak period

Ridership the number of rides taken by people using a public transportation system in a given time period

Ridesharing a form of transportation, other than public transit, in which more than one person shares the use of the vehicle, such as a van or car, to make a trip. Also known as "carpooling" or "vanpooling."

Road Crew the bus driver, train driver or motorman and conductor

Rolling Stock the vehicles used in a transit system, including buses and rail cars

Roster a list showing the allocation of crews to duties

Route Deviation a type of transit service in which a vehicle travels a basic fixed route, picking up or dropping off passengers along the route. On request, and, perhaps, with additional charge, the vehicle will deviate a few blocks from the fixed route to pick up or deliver a passenger

Route Miles (kilometers) the total number of miles (kilometers) included in a fixed route transit system network

Route Number the identification number given to a bus route

Run Number an identification number given to a Bus Duty

Run-out the departure of buses from the depot at the start of the operating day

Schedule a table of times giving details of bus or train crew duties

Service public transport services performed, and the necessary workmanship and material furnished or used in performing the services

Service Area a defined area from within which the majority of transit users will travel to a particular transit facility. A service area is influenced by the level of transit service provided, destinations served, availability of adequate parking, quality and convenience of vehicular access and intermodal transfers, and the relative location and quality of other nearby competing transit facilities

Shift a crew duty

Short Turn a trip that is scheduled to turn back short of the far end of the route

Shuttle a public or private vehicle that travels back and forth over a particular route, especially a short route or one that provides connections between transportation systems, employment centers, etc

Small Bus a bus 28 feet or less in length

Span of Service the number of hours per day that transit service is available

Split Shift or Spreadover a crew duty in two (occasionally more) parts separated by a break of several hours

Stage Carriage a category of local bus service that carries passengers for hire or reward at separate fares, stage by stage, and stopping to pick up or set down passengers at all bus stops along the line of route designated by the Transport Authority as such, and not being express carriages

Standard-Size Bus a bus from 35 to 41 feet in length

Station with respect to intercity and commuter rail, the portion of a property located adjacent to a right-of-way on which intercity or commuter rail transportation is operated, where such portion is used by the general public and is related to the provision of such transportation, including passenger platforms, designated waiting areas, rest rooms and, where a public entity exercises control over the selection, the design, construction or alteration of the property

Streetcar a rail vehicle designed to operate in streets in general traffic

Subscription Bus a commuter bus express service operated for a guaranteed number of patrons from a given area on a prepaid, reserved-seat basis

Suburban Bus a vehicle with front doors only, normally high-backed seats, but no luggage compartments or restroom facilities for use in longer-distance service with relatively few stops. (Such 40 and 45-foot buses are used in the same manner as intercity buses.)

Subway a fixed guideway system constructed in tunnels with underground stations

Target Quality Standards the caliber of service criteria specified in the operating plan

Target Service Levels the future bus or train kilometers, seated capacity and hours of service criteria specified in an operating plan

Terminus the point at the end of a route

Timetable the document showing all the times at which all bus trips on a route

Trackless Trolley See "Trolleybus"

Transfer Center a fixed location where passengers interchange from one route or vehicle to Another

Transit see "Public Transportation."

Transit/Traffic Signal Priority traffic signal technologies designed to expedite the movement of high-occupancy transit vehicles through intersections that may be difficult to navigate or access under normal traffic conditions

Transit agency an entity (public or private) responsible for administering and managing transit activities and services. Transit agencies can directly operate transit service or contract out for all or part of the total transit service provided. When responsibility is with a public entity, it is a public transit agency. When more than one mode of service is operated, it is a multimode transit agency.

Transit Bus a bus with front and center doors, normally with a rear-mounted engine, low-back seating, and without luggage compartments or restroom facilities for use in frequent-stop service

Transit System See "Transit Agency"

Transportation Authority an autonomous statutory agency created by appropriate government Decree

Transportation Demand Management program designed to maximize the people-moving capability of the transportation system by influencing either the time or need to travel

Trip a single journey operated by a bus from one end of the route to the other, or to an intermediate point being used as the terminus for that journey

Trolleybus a rubber-tired electrically powered passenger vehicle operating on city streets drawing power from overhead lines with trolleys.

Trolleybus mode a transit mode using vehicles propelled by a motor drawing current from overhead wires via a connecting pole called a trolley from a central power source not on board the vehicle.

Trolley coach See "Trolleybus"

Trolley replica bus a vehicle with exterior (and usually an interior) designed to look like a streetcar from the early 1900s. (These specialized buses are generally shorter--22 to 32 feet--and are used mostly on historic district and tourist-oriented circulator or shuttle services.)

Turning Point or Turnback an intermediate point on a route at which some trips are scheduled to short turn

Undervalued Ticket a ticket issued for a value less than that paid by the passenger

Unlinked Passenger Trip the number of passengers who board public transportation vehicles. A passenger is counted each time they board a vehicle even though they may be on the same journey from origin to destination

Urban Place a U.S. Bureau of the Census-designated area (less than 50,000 population) consisting of closely settled territory not populous enough to form an urbanized area.

Urbanized Area (UZA) an area defined by the U.S. Census Bureau that includes one or more incorporated cities, villages and towns (central place) and the adjacent densely settled surrounding territory (urban fringe) that together have a minimum of 50,000 persons. The urban fringe generally consists of contiguous territory having a density of at least 1,000 persons per square mile. UZAs do not conform to congressional districts or any other political boundaries. Most U.S. government transit funding is based on urbanized areas.

Van a 20-foot long or shorter vehicle, usually with an automotive-type engine and limited seating normally entered directly through side or rear doors rather than from a central aisle, used for demand response, vanpool, and lightly patronized motorbus service

Vanpool an arrangement in which a group of passengers share the use and cost of a van in traveling to and from pre-arranged destinations together

Variable Cost a cost that varies in relation to the level of operational activity

Vehicle Hours the hours a vehicle travels from the time it pulls out from its garage to go into revenue service to the time it pulls in from revenue service. It is often called platform time. For conventional scheduled services, it includes revenue time and deadhead time.

Vehicle Miles (kilometers) the total number of miles 9 kilometers) traveled by public transport vehicles. Commuter rail, heavy rail and light rail report individual car miles (kilometers) rather than train miles (kilometers) for vehicle miles (kilometers)

Vehicle Revenue Hours the hours traveled when the vehicle is in revenue service (i.e., the time when a vehicle is available to the general public and there is an expectation of carrying passengers). These passengers either directly pay fares, are subsidized by public policy, or provide payment through some contractual arrangement. Vehicles operated in fare free service are considered in revenue service. Revenue service excludes school bus service and charter service. For conventionally scheduled services, vehicle revenue hours are comprised of 2 elements: running time and layover/recovery time.

Vehicle Revenue Miles the miles traveled when the vehicle is in revenue service (i.e., the time when a vehicle is available to the general public and there is an expectation of carrying passengers). These passengers either directly pay fares, are subsidized by public policy, or provide payment through some contractual arrangement. Vehicles operated in fare free service are considered in revenue service. Revenue service excludes school bus service and charter service. For conventionally scheduled services, vehicle revenue miles are comprised of running miles only.

Vehicle Trip a trip by a single vehicle regardless of the number of people in the vehicle

This page intentionally left blank.

Appendix C – References

This page intentionally left blank.

References

1. Abdelfattah, A.M. "Bus Delays in Mixed Traffic: A Challenge for Intelligent Transportation Systems." *Transportation Frontiers for the New Millennium: 69th Annual Meeting of the Institute of Transportation Engineers*, Las Vegas, Nevada, 1999, p. 15.
2. *Access by Design: Transit's Role in Land Development, A Designer's Manual*. Maryland Department of Transportation, Mass Transit Administration, September 1988.
3. Addenbrooke, P., D. Bruce, F. Courtney, S. Hellewell, A. Nisbet, and T. Young. *Urban Road Planning and Design for Road Public Transport*. Confederation of British Road Passenger Transport, London, 1981.
4. Albee, Kathryn, et al. *Transit Facility Design Guide.* Conducted for Capital Metropolitan Transportation Authority, Austin, Texas, 1988.
5. American Association of State Highway and Transportation Officials. *Guide for the Design of Park-and-Ride Facilities*. Washington, D.C., 1991.
6. American Association of State Highway and Transportation Officials. *Guide for the Design of High Occupancy Vehicle Facilities*. Washington, D.C., 1991.
7. Ayres-Palanuk, Kerry and Katharine Hunter-Zaworski. *Bus Rapid Transit, A Smart Alternative for Medium Sized Communities*. Prepared for U.S. Department of Transportation, Washington, D.C., 1997.
8. Balke, Kevin N., Conrad L. Dudek, and Thomas Urbanik II. *Development and Evaluation of an Intelligent Bus Priority Concept*. Paper 00-1543. Presented at the Transportation Research Board 79th Annual Meeting. Transportation Research Board, Washington, D.C., January 2000.
9. Baltes, Michael R. Statistical Estimation of the Importance Customers Place on Specific Elements of Bus Rapid Transit. *Journal of Public Transportation*, Volume 6, No. 4, 2003.
10. Baltes, Michael R. Bus Rapid Transit: A Vital Component in the Overall Solution, FL Section ITE, *FLITE*, Volume 42, No. 1. June 2003, pg. 5.
11. Baltes, Michael R. and Steven Polzin. Bus Rapid Transit: A Viable Alternative. *Journal of Public Transportation*, Volume 5, No. 2, 2002.
12. Batz, T.M. *High occupancy Vehicle Treatments Impacts and Parameters (A Synthesis).* Vol. 1, Procedures and Conclusions. Vol. 2, Bibliography and Data. New Jersey Department of Transportation, Trenton, New Jersey, 1986.
13. Ben-Akiva, Moshe, and Takayuki Morikawa, *Ridership Attraction of Rail Compared with Bus*. Report prepared for Urban Mass Transportation Administration, U.S. Department of Transportation. Massachusetts Institute of Technology, 1991.
14. Berrick, M. and R. Cevero. *Transit Based Residential Development in the United States*. Federal Transit Administration, Washington, D.C., March 1994.
15. Bevington, Ellen and Kern L. Jacobson. *AVI for Bus Priority at Traffic Signals in the Puget Sound Region*. Presented at TRB 1994 International Conference on High Occupancy Vehicle Facilities, Los Angeles, California, June 5-8, 1994.
16. Biehler, Allen D. "Exclusive Busway versus Light Rail: A Comparison of New Fixed Guideways." *Light Rail Transit: New System Successes at Affordable Prices*. Special Report 221, Transportation Research Board, Washington, D.C., 1988, pp. 89-98.
17. Birk, M.L. and P.C. Zegras. *Moving toward Integrated Transport Planning: Energy, Environment, and Mobility in Four Asian Cities*. International Institute for Energy Conservation, Washington, D.C., 1993.
18. Bonsall, J.P., Transitways, The Ottawa Experience in Proceedings – Second National Conference of High-Occupancy Vehicle Lanes and Transitways, Houston, Texas, October 25-28, 1997, edited by Lancaster, A. and Lomax, T., Transportation Research Board, National Research Council, pp. 59-76.

19. Brothers, B.T., D.E. Benson, and W.V. Sheppard. "Regional Plan of Preferential Facilities for High Occupancy Vehicles." *Transportation Research Record*, No. 546, 1975.
20. BRT Bus Rapid Transit – Why More Communities are Choosing Bus Rapid Transit. Transportation Research Board, National Research Council, Washington D.C. 2001.
21. Buckley, S. M., and A.M. Miller. 2000. *Institutional aspects of Bus Rapid Transit—A Macroscopic Examination.* California PATH Program, Institute of Transportation Studies, University of California, Berkeley.
22. *Building Livable Communities with Transit*. Federal Transit Administration, Office of Planning, September 1999.
23. *Bus Priority – Proceedings of a Symposium Held at TRRL, 1972.* Transport and Road Research Laboratory, Department of the Environment, TRRL Report LR 570, 1973.
24. *Bus Priority Systems in Brazil: From Theory to Practice*. PTRC Summer Annual Meeting, September 1987.
25. *Bus Priority Systems*. NATO Committee on the Challenges of Modern Society. CCMS Report No. 5, Transport and Road Research Laboratory, Department of the Environment, 1976.
26. Bus Rapid Transit Demonstration Program, Federal Transit Administration, 1990.
27. "Bus Rapid Transit Doesn't Have to be on Rails." *Bus World*, 1989. Reprint.
28. "Bus Rapid Transit Pilot Program Continues Steady Progress in Oregon." *Urban Transportation Monitor*, 1999.
29. Calthorpe Associates in association with Mintier & Associates. *Transit-Oriented Development Design Guidelines.* Prepared for Sacramento County planning and Community Development Department, November 1990.
30. Camph, D.H. 1997. *Dollars and sense: The economic case for public transportation in America.* Washington, DC: Campaign for Efficient Passenger Transportation.
31. Carey, G.N., S.M. Viggiano, and L. Gardner. *The Development of a Guided Bus System: The Eugene/ Springfield Experience*. Institute of Transportation Engineers 68th Meeting, Toronto, Ontario, 1998.
32. Cevero, Robert and Samuel Seskin. *An Evaluation of the Relationships between Transit and Urban Form.* Transit Cooperative Research Program Research Results Digest No. 7, Transportation Research Board, Washington, D.C., 1995.
33. Chandler, K. et al. *Alternative Fuel Transit Bus Evaluation Program Results.* Report No. 961082, Society of Automotive Engineers, May 1996.
34. *Chicago's Contra-Flow Bus Lanes Safety and Traffic Impacts.* The Mayor's Traffic Management Task Force for the City Council Committee on Traffic Control and Safety, June 1983.
35. Christiansen, Dennis and Daniel Morris. *An Evaluation of the Houston High-Occupancy Vehicle Lane System*. Texas Transportation Institute, College Station, Texas, June 1991.
36. Clark, S., R. Liu, F. Montgomery, and J. Tate. *A Microscopic Evaluation of Kerb Guided Bus Schemes*. Presented at the Transportation Research Board 79th Annual Meeting. Transportation Research Board, Washington, D.C., January 2000.
37. Clarkamas County Long Range Planning, Department of Transportation and Development. November, 2000. *Damascus concept planning study.*
38. Cornwell, P.R. and J.A. Cracknell. *The Case for Busway Transit*. PTRC Summer Annual Meeting, September 1990.
39. Crain & Associates, Inc. "The Martin Luther King, Jr. East Busway in Pittsburgh, PA." Report No. UMTA-PA-06-0081-86-1. October 1987.
40. Crain & Associates, Inc., In association with Southern California Association of Governments. "Evaluation of Express Busway on San Bernardino Freeway – Third Year Report (Final Report)." Prepared for the Urban Mass Transportation Administration, Washington, D.C., 1976.

41. Crowell, W.H. *Preferential Bus Lanes on Urban Arterials, Selected Studies on Their Feasibility and Performance*. Polytechnic Institute of New York, Report to UMTA, Washington, D.C., December 1978.
42. Daugherty, G.G. and R.J. Balcombe. *Leeds Guided Busway Study.* Crowthorne: Berkshire: Transport Research Laboratory, 1999.
43. Davis, J.E., N.L. Nihan, and L.N. Jacobson. *HOV Improvements on Signalized Arterials*. Presented at the Transportation Research Board 70th Annual Meeting, Washington, D.C., January 1991.
44. Deardorf, Raymond G., et al. *Measuring Station Capacity for Seattle Bus Busway.* Presented at the 1986 Annual Meeting of the Transportation Research Board.
45. Delcan Corporation. "Report on the Feasibility of a Grade Separated Transitway through the Central Area of Ottawa." September, 1988.
46. DeLeuw, C.E., and W.R. McConochie. *Exclusive Lanes for Express Bus Operation*. Prepared for American Transit Association Western Regional Conference, San Francisco, April 22, 1963.
47. *Designing for Transit: A Manual for Integrating Public Transportation and Land Use in Monterey County.* Monterey-Salinas Transit (MST), California, January 1996.
48. Diaz, Roderick and Donald Schneck. "An Overview of Bus Rapid Transit Technologies in the Americas." Paper 00-0631. Presented at the Transportation Research Board 79th Annual Meeting, Transportation Research Board, Washington, D.C., January 2000.
49. *Diesel Emission Control – Sulfur Effects Program Phase 1 Interim Data Report No. 3*. Sponsored by the U.S. Department of Energy, Engine Manufacturers of Emission Control Association, November 1999.
50. Dobbies, John J. *Customer Information at Bus Stops.* Transit Cooperative Research Program Synthesis of Transit Practice 17, Transportation Research Board, Washington, D.C., 1996.
51. Dunn. "ITS Projects, Products, and Progress In New Zealand." Paper No. 3026. *Towards The New Horizon Together: Proceedings Of The 5th World Congress On Intelligent Transport Systems*, 12-16 October 1998, Seoul, Korea.
52. Federal Highway Administration. *Results of Case Studies and Analysis of Busway Applications in the United States*. Report OS-20034, Washington, D.C., January 1973.
53. Federal Transit Administration (FTA) Office of Research, Demonstration and Innovation. 2000. *Issues in Bus Rapid Transit.*
54. Federal Transit Administration, Office of Research, Demonstration and Innovation. *Bus Rapid Transit Demonstration Program.* Washington, D.C., January 1988.
55. Federal Transit Administration. Office of Research, Demonstration and Innovation. *Characteristics of Bus Rapid Transit for Decision-Making.* Washington, D.C., 2004.
56. Fernandez, Rodriguez. "An Expert System for the Preliminary Design and Location of High Capacity Bus Stops." *Traffic Engineering & Control*, Vol. 34, No. 11, November 1993.
57. *Final Environmental Impact Statement, Downtown Seattle Transit Project*. Municipality of Metropolitan Seattle, Seattle, Washington, June 5, 1985.
58. Fitzpatrick, Kay, Nowlin, Lewis, et al, Texas Transportation Institute. *Location and Design Guidelines for Bus Stops Final Report*. Transit Cooperative Research Program Project A-10, Transportation Research Board, June 1996.
59. Fitzpatrick, Kay, T. Urbanik II, and Robert W. Stokes. *Guidelines for Planning, Designing and Operating Bus-related Street Improvements.* Prepared by the Texas Transportation Institute, Austin, Texas State Department of Highways and Public Transportation, August 1991.
60. Fuhs, Charles A. *Preferential Lane Treatments for High-Occupancy Vehicles*. Transportation Research Board, Washington, D.C., 1993.

61. Gardner Systems. *Improved Traffic Signal Priority for Transit*. Transit Cooperative Research Program Project A-16 Interim Report. Transportation Research Board, Washington, D.C., December 1998.
62. Gardner, G., P.R. Cornwell, and J.A. Cracknell. *The Performance of Busway Transit in Developing Cities*. TRRL Research Report 329, Crowthorne, Berkshire, RG11 6AU, 1991.
63. Gardner, L. *Bus Rapid Transit: An Innovative Transit Strategy for Medium-Sized Cities*. Washington State Department of Transportation, Sixth National Conference on Transportation Planning for Small and Medium Sized Communities, Spokane, Washington, 1999.
64. Gas Research Institute. *A Comparison of LNG, CNG, and Diesel Transit Bus Economics*. Report No. GRI-93/0421. Prepared by Acurex Environmental Corporation, October 1993.
65. Gatens, D.M. *Locating and Operating Bus Rapid Transit Park-Ride Lots: A Synthesis of Experience and Some Preliminary Planning Guidelines*. Urban Mass Transportation Administration, University of Washington, Seattle, August 1973.
66. Gatens, Daniel M. *Locating and Operating Bus Rapid Transit Park-Ride Lots: A Synthesis of Experience and Some Preliminary Planning Guidelines*. Research Report 73-3, UMTA-URT-3-73-3, University of Washington, Seattle, August 1973.
67. General Accounting Office. *Use of Alternative Fuels in Transit Buses*. December 1999.
68. "Giants Jump on Dulles Bus/Rail Project." *Public Works Financing*, February 1999.
69. Gibson, J., I. Baeza, and L. Willumsen. *Bus Stops, Congestion, and Congested Bus Stops. Traffic Engineering and Control.* June 1989.
70. Gillen, David W. *The Effects of Federal Government Parking Policy on Modal Choice Among Federal Government Employees in Ottawa*. Department of Economics, University of Alberta. Prepared for the Transport Canada, Research and Development Centre, Montreal, Quebec, March 1977.
71. Glennon, John D. and Vergil G. Stover. *A System to Facilitate Bus Rapid Transit on Urban Freeways, The Technical Feasibility of Using Traffic Surveillance and Control Techniques*. Texas Transportation Institute, College Station, Texas, 1968.
72. Gluck, Jerome S. *Preferential Treatment for Buses: An Analysis of Their Impact on Various Urban Sectors*. U.S. Department of Transportation, Urban Mass Transportation Administration, Washington, D.C., March 1978.
73. Goodman, L. and J.M. Lutin. "Transportation Terminals." *Transportation Planning Handbook*, 2nd ed., Institute of Transportation Engineers, Washington, D.C., 1999.
74. Gravel, M. and R.W. Boves. "Why Bus-Based Rapid Transit is the Key to Sustainable Transportation." International Road Federation, XIIIth World Meeting of the International Road Federation, Toronto, Canada, 1997.
75. Greater London Council, Planning and Transportation Department. *Bus Only Lanes*. May 1970.
76. *Guided Bus Rapid Transit – Proceedings of an International Seminar.* SAGRIC International, Adelaide, South Australia, 1989.
77. *Guidelines for Preferential Treatment for High Occupancy Vehicles*. The Transportation Energy Management Program, Ontario Ministry of Transportation and Communications, 1985.
78. *Guidelines for the Location and Design of Bus Stops.* Transit Cooperative Research Program Report 19, Transportation Research Board, Washington, D.C., 1996.
79. Haywood, Howard M. October 1999. *Massachusetts Bay Transportation Authority Bus-Rapid Transit Silver Line.*
80. *High Occupancy Vehicle Project Case Studies: Historical Trends and Project Experiences*. U.S. Department of Transportation, August 1992.
81. Hillmer, Jon and Stephen T. Parry. "The El Monte Busway, A Twenty-Year Retrospective." Presented at the Transportation Research Board 7th National Conference on

High-Occupancy Vehicle Systems, Transportation Research Board, Los Angeles, California.

82. Hirsch, M. "Giving the Bus Priority: Consideration and Benefits." *Transit Journal*, February, 1976.
83. Hirsch, M. *Impact of Arterial Bus Priority Treatments on Bus Operating Costs*. Transit Development Corporation and Urban Mass Transportation Administration, 1975.
84. Hoehn, J. *A Sustainable Urban Transportation System: The Surface Metro in Curitiba, Brazil*. The University of Wisconsin, Madison Wisconsin, 1995.
85. Hounsell, N. and M. McDonals. *Evaluation of Bus Lanes*. TRRL Contractor Report, 1988.
86. Hounsell, N., J. Landles, R. Bretherton, and K. Gardner. "Integrated Traffic Control and Bus Priority Systems in London: Results from the INCOME Project." Paper No. 20. *Towards the New Horizon Together: Proceedings of the 5th World Congress on Intelligent Transport Systems*. Held October 12-16, 1998, Seoul, Korea, 1998.
87. Howard, Needles, Tammen, and Bergendoff. *Feasibility Study for Bus Rapid Transit on the Shirley Highway Corridor.* Metropolitan Washington Council of Governments, March 1970.
88. Huntley, P. "Guided Bus: Rapid Transit on a Tight Budget." *Local Transport Today.* March 9, 1992.
89. *Hybrid-Electric Drive, Heavy-Duty Vehicle Testing Project Final Emissions Report*. Northeast Advanced Vehicle Consortium, M.S. Bradley & Assoc., Inc., West Virginia University, 2000.
90. Institute of Transportation Engineers. *A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility. Washington, D.C., 1997.*
91. Institute of Transportation Engineers. *A Toolbox for Alleviating Traffic Congestion*. Washington, D.C., 1997.
92. Institute of Transportation Engineers. *Design Features of High Occupancy-Vehicle Lanes*. Washington, D.C., 1991.
93. Institute of Transportation Engineers. *Guidelines for High-Occupancy-Vehicle (HOV) Lanes, A Recommended Practice*. Publication No. RP-017. Washington, D.C., 1986.
94. Institute of Transportation Engineers. *Implementing Effective Travel Demand Management Measures*. Washington D.C., 1993.
95. Institute of Transportation Engineers. *The Effectiveness of High-Occupancy Vehicle Facilities*. Washington, D.C., 1988.
96. Jacobson, J. and Y. Sheffi. *Analytical Model of Traffic Delays Under Signal Preemption: Theory and Application.* Presented at the 59th Annual Meeting of the Transportation Research Board, Washington, D.C., 1980.
97. "Keeping Buses Moving. A Guide to Traffic Management to Assist Buses in Urban Areas," *Local Transport Note.* December 1991.
98. Khan, A.M. "Cost Efficiency and Service Level Comparisons of Transitway and Light Rail Transit." *Proceedings of the 6th World Conference on Transport Research*, Lyon, France, 1992, pp. 2149-60.
99. King, Rolland D. *New Designs and Operating Experiences with Low-Floor Buses*. Transit Cooperative Research Program Report 41, Transportation Research Board, Washington, D.C., 1998.
100. Kloos, W.C., A.R. Danaher, and K.M. Hunter-Zaworski. 1994. Bus priority at traffic signals in Portland: The Powell Boulevard pilot project. *Compendium of Technical Papers.* Institute of Transportation Engineers: 420-424.
101. Kloos, W.C., and K.Turner. 1999. Implementing traffic signal priority for buses. *Compendium of Technical Papers.* Institute of Transportation Engineering.
102. Koffman, David and Richard Edminster. *Streets for Pedestrian and Transit: Examples of Transit Malls in the United States*. Report No. UMTA-MA-06-0049-77-11, August 1977.

103. Kohler, U. "Capacity of Transit Lanes." *Proceedings of the International Symposium on Highway Capacity*, Karlsruhe, Germany, July 1991.
104. Kropidlowski, C.R. "Chicago Contraflow and Concurrent Flow Bus Lane Experience." *Compendium of Technical Papers*, Institute of Transportation Engineers, 1988.
105. KRW, Inc. *Guidelines for Transit Facilities Signing and Graphics*. Transit Cooperative Research Program Report 12, Transportation Research Board, Washington, D.C., 1996.
106. Lane Transit District. November, 2000. *Lane Transit District Bus-Rapid Transit, Draft Environmental Assessment*
107. Levinson, Herbert S. and K.R. St. Jacques. "Bus Lane Capacity Revisited." *Transportation Research Record*, No. 1618, 1998.
108. Levinson, Herbert S., Lawrence Lennon, and Jerry Cheng. "Downtown Space for Buses – the Manhattan Experience." *Transportation Research Record*, No. 1308, 1991.
109. Levinson Herbert S., et al NCHRP Reports 143 and 155 Bus Use of Highways, Highway Research Board, National Research Council, Washington D.C. 1973, 1975.
110. Levinson, Herbert S.. "Transportation Systems Management – How Effective? Some Perspectives on Benefits and Impacts." *Transportation Research Record*, No. 1142, 1987.
111. Levinson, Herbert S. "HOV Lanes on Arterial Streets." Paper presented at 2nd National HOV Lane and Transitway Conference, Houston, Texas, October 27, 1987.
112. Levinson, Herbert S. and K.R. St. Jacques. "Bus Lane Capacity Revisited." *Transportation Research Record*, No. 1618, 1998.
113. Lin, Hanghai. "Bus Capacity under Mixed Traffic Conditions." *Transportation Research Record No. 1372*, 1992.
114. Lloyd-Jones, Tony. *Curitiba: Sustainability by Design.* Urban Design Group Resources Page on the Internet, 1997.
115. Lomax, T., S. Turner, G. Shunk, H.S. Levinson, R.H. Pratt, P.R. Bay, and B.G. Douglas. *Quantifying Congestion, Final Report*. National Cooperative Highway Research Program 7-13, Transportation Research Board, September 1995.
116. Marshall, Leo F., Herbert S. Levinson, Lawrence C. Lennon, and Jerry Cheng. "Bus Service Times and Capacities in Manhattan." *Transportation Research Record*, No. 1266, 1990
117. Mass Transit – Bus Rapid Transit Shows Promise – Report to Congressional Requesters – General Accounting Office – Washington, D.C. GAO 6-01-984, Washington, D.C.
118. McCormick Rankin International with Michael Baker, Jr. *Bus Rapid Transit for Charlotte: Issues and Opportunities: Executive Summary*. February 1996.
119. McCormick Rankin International. 1998. *Metropolitan Brisbane Busway Program—Busway Planning and Design Manual.* Brisbane: Brisbane City Council/Queenland Transport.
120. *Metro Transportation Facility Design Guidelines*. Metro (Municipality of Metropolitan Seattle), Seattle, Washington, D.C., 1991.
121. Metro, July 1994. *Region 2040, Decisions for tomorrow, transportation analysis of the growth concept.*
122. Metro, Municipality of Metropolitan Seattle. *Encouraging Public Transportation through Effective Land Use Actions*. U.S. Department of Transportation, Technology Sharing Program, Washington, D.C., 1987.
123. Metro. 2000. *Regional land information system (RLIS).* Portland, Oregon.
124. Metropolitan Transit Authority of Harris County (METRO). *Transitway Projects.* October 1987.
125. Metropolitan Transportation Authority, Los Angeles County and City of Los Angeles Department of Transportation. *Metro Rapid Bus Demonstration Program Update.* January 2000.

126. Mirabdal, J. "Traffic Signal Treatments of Transit Vehicles in San Francisco." 67th Annual Meeting of the Institute of Transportation Engineers, Boston, Massachusetts, August 1997.
127. Mitretek Systems. *Bus Rapid Transit-ITS Concept of Operations White Paper*. Prepared for the Bus Rapid Transit Demonstration Program Workshop – Transit Operations, Traffic Engineering, and Infrastructure, Miami, Florida, May 15-16, 2000.
128. Mounce, J.M., H.G. Hawkins, H.S. Payne, R.W. Stokes. *Revised Manual for Planning, Designing, and Operating Transitway Facilities in Texas*. Research Report 339-14, Texas Transportation Institute, College Station, TX, August 1988.
129. New York City Department of Transportation, Bureau of Transit Operations. *Improving the Efficiency of Bus Priority Treatments – Final Report*. October 1992.
130. Nisar, M., A.M. Khan, and W.F. Johnson. "Transitways Offer Superior Level of Service and Economic Efficiency." *Transport Policy, Management, and Technology Towards 2001 – Selected Proceedings of the Fifth World Conference on Transport Research*, Vol. 3, Yokohama, Japan, 1989, pp. 247-61.
131. OC Transpo. *Operating and Capital Cost Benefits of Transitway Construction, 1982-95*. February, 1986.
132. OECD Road Research Group. *Bus Lanes and Busway Systems*. Paris, 1977.
133. Options for Granville Mall: Transit Evaluation. BC Transit, Vancouver Regional Transit System, February 8, 1988.
134. Parsons Brinckerhoff Quade & Douglas, Inc. *Transitway Development Program for Orange County*. Prepared for the Orange County Transit District, October, 22, 1988.
135. Parsons Brinckerhoff, Batelle. 2001. Tri-Met 5-year Intelligent Transportation Systems plan. *Final Report*. Portland, Oregon.
136. Parsons, Brinckerhoff, Quade & Douglas, Inc. *Transit and Urban Form.* Transit Cooperative Research Program Report 16, Vols. 1 and 2, Transportation Research Board, Washington, D.C., 1997.
137. Parsons-Brinckerhoff et al. *Take-a-Lane Study.* Prepared for Regional Transit Project, Metro Transit, Seattle, 1992.
138. Patton, Carl V. et al. 1993. *Basic methods of policy analysis and planning.* Englewood Cliffs, NJ: Prentice Hall.
139. Pleasant Valley Concept Plan. March/April 2001. *Public Comment Report, Community Forums* 1&2.
140. Polzin, S.E. 1999. The transportation—land use relationship: Public transit's impact on land use. ASCE Journal of Urban Planning. (December).
141. Porter, Douglas R. *Transit-Focused Development*. Transit Cooperative Research Program Synthesis of Transit Practice 20, Transportation Research Board, Washington, D.C., 1997.
142. PPK Environment & Infrastructure. *Bus Stop Style Guide.* Prepared for the State Transit Authority of New South Wales, 1999.
143. Priority Bus Treatments. New York City Department of Transportation, February 1982.
144. Priority Techniques for High Occupancy Vehicles – State-of-the-Art Overview. Transportation Systems Center, Cambridge, Massachusetts, November 1975.
145. Project for Public Spaces, Inc. *The Role of Transit in Creating Livable Metropolitan Communities*. Transit Cooperative Research Program Report 22, Transportation Research Board, Washington, D.C., 1997.
146. Project For Public Spaces, Inc. *Transit-Friendly Streets: Design and Traffic Management Strategies to Support Livable Communities*. Transit Cooperative Research Program Report 33, Transportation Research Board, Washington, D.C., 1998.
147. Project for Public Spaces, Inc. and Multisystems, Inc. *The Role of Transit Amenities and Vehicle Characteristics in Building Transit Ridership: Amenities for Transit Handbook and the Transit Design Game Workbook.* Transit Cooperative Research Program Report 46, Transportation Research Board, Washington, D.C., 1999.

148. Pultz, Susan, and David Koffman. *The Martin Luther King, Jr. Busway in Pittsburgh, PA.* U.S. Department of Transportation, October, 1987.
149. Pushkarev, B.S. and S.M. Zupan. *Public Transportation and Land Use Policies*. Indiana University Press, 1977.
150. Queensland Transport. 1997. *Integrated regional transport plan for South East Queensland.* Brisbane: Queensland Government.
151. R.H. Pratt Associates. *A Study of Low Cost Alternatives to Increase the Effectiveness of Existing Transportation Facilities: Volume II – Results of Case Studies and Analysis of Busway Applications in the United States,* U.S. Department of Transportation, Office of the Secretary, January 1973.
152. Rabinovitch, Jonas, and John Hoehn. *A Sustainable Urban Transportation System: "The Surface Metro" System in Curitiba, Brazil*. EPAT/MUCIA, Washington, D.C., May 1995.
153. Rabinovitch, Jonas, and Josef Leitmann. *Environmental Innovation and Management in Curitiba, Brazil*. Working Paper No. 1. UNDP/UNCHS (Habitat)/World Bank, Washington, D.C., June 1993.
154. Rabinovitch, Jonas. "Curitiba: Towards Sustainable Urban Development." *Environment and Urbanization*, Vol. 4, No. 2., October 1992.
155. Rathbone, Daniel B. *Creating Exclusive ROW for Buses by using Reversible Lanes*. Presented at the Bus Rapid Transit Workshop on Transit Operations, Traffic Engineering, and Infrastructure, Miami, Florida, May 15, 2000.
156. Replogle, M. *Transportation Conformity and Demand Management: Vital Strategies for Clean Air Attainment*. (Draft) Environmental Defense Fund, 1993.
157. Rutherford, G.S., S. McLachlan, and K. Semple. *Transit Implications of HOV Facility Design*. Federal Transit Administration, Office of Planning, 1995.
158. Scannell, Ed. May 12, 2000. Los Angeles takes first step toward Bus Rapid Transit. *The Urban Transportation Monitor:*1.
159. Schneider, W. and A. Beechbuhl. *Defining the Low-Floor Bus: Its Advantages and Disadvantages*. Presented at the International Union of Public Transport 49th International Congress, Stockholm, August 1991.
160. Schwarz, Marcy and Constance Eichhorn. 1996. *Collaborative decision making: use of multiattribute utility analysis to involve stakeholders in resolving controversial transportation issues.*
161. Shen, L. David, H. Elbadrawi, F. Zhao, and Diana Ospina. *At-Grade Busway Planning Guide.* National Urban Transit Institute, Florida International University, University Park, Florida, December 1998.
162. Sislak, K.G. *Electric Trolleybus: The Zero Emission Fuel for the Euclid Corridor Bus.* American Public Transit Association, 1999 APTA Bus Conference, Cleveland, Ohio, 1999.
163. Skabardonis, Alexander. "Control Strategies for Transit Priority." Paper 00-1584. Presented at the Transportation Research Board 79th Annual Meeting. Transportation Research Board, Washington, D.C., January 2000.
164. State of California Business and Transportation Agency, Office of Traffic, Department or Transportation. *Busways and Related HOV Facilities and Programs*. March 1978.
165. St. Jacques, Kevin and Herbert S. Levinson. *Operational Analyses of Bus Lanes on Arterials.* Transit Cooperative Research Program Report 26, Transportation Research Board, 1997.
166. "Surface Transit Project." Presented by Martha Wellborne at *A Lecture and Symposium on the Role of Transit in Shaping Our Cities*. Los Angeles, California, March 7, 2000.
167. Tebb, R.G.P. "'Guiding Light' – the Roles of Bus Transit and Guided Busways as Practical Planning for Public Transport." *Planning for Public Transport – A Dying Art? 21st Annual Public Transport Symposium*, University of Newcastle Upon Tyne, Department of Civil Engineering, March 27-29, 1990.

168. Texas Transportation Institute, Texas A&M Research Foundation, and Texas A&M University. *Guidelines for the Location and Design of Bus Stops.* Transit Cooperative Research Program Report 19, Transportation Research Board, Washington, D.C., 1996.
169. Texas Transportation Institute. *Feasibility of Priority Lane Pricing on the KATY HOV Lane: Feasibility Assessment*. College Station, Texas, 1998.
170. *The Performance of High-Flow Bus Lanes in Bangkok.* TRRL Supplementary Report SR723, TRRL, Crowthorne, 1982.
171. *Transforming Transportation in the Euclid Corridor*. Greater Cleveland Regional Transit Authority, 1999.
172. *Transitways*. American Public Transit Association, Washington, D.C., 1987.
173. Transport and Road Research Laboratory. *Study of Bus Priority Systems for Less Developed Countries*. United Kingdom Department of Transport, May 1989.
174. Transport and Road Research Laboratory. *Study of Bus Priority Systems for Less Developed Countries*. United Kingdom Department of Transport, May 1989.
175. *Transport in the Urban Environment.* Institute of Highways and Transportation, London, UK, June 1997.
176. Transport Research Laboratory, Overseas Center. *Design Guidelines for Busway Transit*. Nov. 12, 1993.
177. Transportation and Parking For Tomorrow's Cities Prepared by Wilbur Smith and Associates, under commission from Automobile Manufacturers' Association, 1966, H.S. Levinson Principal Investigator.
178. Transportation Research Board. National Academy Press. 1996. TCRP Report 19., *guidelines for the location and design of bus stops.* Washington, DC.
179. Transportation Research Board. 2000. *Bus Rapid Transit: Why more communities are choosing Bus Rapid Transit.*
180. Transportation Research Board. 2001. BRT --*Bus Rapid Transit:* Washington, DC.
181. Tyler, Nicholas. "The Design of High Capacity Bus Systems: The Use of Fuzzy Supports to Represent Expert Opinion." *Selected Proceedings, 6th World Conference on Transport Research*, Lyon, France, 1992.
182. U.S. General Accounting Office. 2001. *Mass transit: Bus Rapid Transit shows promise.* Washington, DC.
183. Vincent, R.A., B.R. Cooper, and K. Wood. *Bus Actuated Signal Control at Isolated Intersections: Simulation Studies of Bus Priority*, Report 814, Transportation and Road Research Laboratory, Berkshire, United Kingdom, 1978.
184. Vuchic, V.R. 1999. *Transportation for Livable Cities.* New Brunswick: Center for Urban Policy Research.
185. Vuchic, V.R. 2000. Comparison of light rail transit with bus semirapid transit. *5th UITP Light Rail Conference, Melbourne. Brussels: UITP.*
186. Vuchic, V.R. 2002. Bus Semirapid transit as an option in analysis of alternative transit modes. *Journal of Public Transportation* 5 (2).
187. Vuchic, Vukan, with Eric C. Bruun, Nikola Krstanoski, and Yong Eun Shin, University of Pennsylvania. *The Bus Transit System: Its Underutilized Potential*. Federal Transit Administration, Washington, D.C., May 1994.
188. Walker, Mark. *On-Street Priority Transit Facilities: Improving Urban Mobility Using Available Rights-of-Way.* Paper 00-0897. Presented at the Transportation Research Board 79th Annual Meeting. Transportation Research Board, Washington, D.C., January 2000.
189. Weant, R.A. and H.S. Levinson. *Parking*. ENO Foundation for Transportation, Westpoint, Connecticut, 1990.
190. WestStart. February 8, 2001. *Bus-Rapid Transit and the American community, a national planning and design competition.*

191. Wilbur Smith and Associates. 1975. *Bus Rapid Transit options for densely developed areas*.
192. Wilson, Tom and Alan Wayte. *Guided Bus Rapid Transit Seminar, Northeast Busway Adelaide: Operating System and Performance*. Adelaide, Australia, October 1988.
193. Wilson, Tom. *Busway Patronage – June 1988.* State Transport Authority, South Australia, Australia, June 1988.
194. Wohlwill, D.E. *Development along a Busway: Case Study of Development along the Martin Luther King, Jr. East Busway in Pittsburgh, Pennsylvania*. Port Authority of Allegheny County, Pittsburgh, PA, 1996.
195. Wu, J. and N. Hounsell. "Bus Priority Using Pre-Signals." *Transportation Research, Part A*. 1998, pp. 563-83.