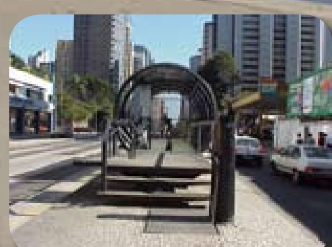
United States
Department of Transportation

Federal Transit Administration
Office of Research, Demonstration and Innovation

Characteristics of BUS RAPID TRANSIT for Decision-Making

Project No. FTA-FL-26-7109.2009.1
February 2009

Photo courtesy of Los Angeles County Metropolitan Transportation Authority



Characteristics of
BUS RAPID TRANSIT
for Decision-Making

funded by the Federal Transit Administration

FTA Project Manager: Helen M. Tann
Transportation Program Specialist
Federal Transit Administration
Office of Research, Demonstration and Innovation
1200 New Jersey Ave, SE
Washington, DC 20590

Principal Investigator: Dennis Hinebaugh
Director, National BRT Institute
Center for Urban Transportation Research
University of South Florida (USF)
4202 E. Fowler Ave, CUT100
Tampa, FL 33620

NOTICE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE February 2009	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

Characteristics of Bus Rapid Transit for Decision-Making (CBRT)

5. FUNDING NUMBERS

FL-26-7109

6. AUTHOR(S)

Roderick B. Diaz (editor) Dennis Hinebaugh, National Bus Rapid Transit Institute (Director)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Bus Rapid Transit Institute
Center for Urban Transportation Research
University of South Florida
4202 E. Fowler Avenue, CUT100
Tampa, FL 33620

8. PERFORMING ORGANIZATION REPORT NUMBER

FL-26-7109-05

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Transit Administration
Office of Research, Demonstration and Innovation (TRI)
1200 New Jersey Avenue, SE
Washington, DC 20590

10. SPONSORING/ MONITORING AGENCY REPORT NUMBER

FTA-FL-26-7109.2009.1

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Available From: National Bus Rapid Transit Institute, Center for Urban Transportation Research, University of South Florida, 4202 E. Fowler Avenue, CUT100, Tampa, FL 33620
Also available through NBRTI web site: https://www.nbrti.org

12b. DISTRIBUTION CODE

13. ABSTRACT

The Characteristics of Bus Rapid Transit for Decision-Making (CBRT) report was prepared to provide transportation planners and decision makers with basic information and data to support the development and evaluation of bus rapid transit concepts as one of many options during alternatives analyses and subsequent project planning. This report provides information on BRT systems in a single, easy to use reference tool for transportation planners in selecting from the large array of BRT elements and integrating them into comprehensive systems.

The CBRT report explores BRT through a progression of three different perspectives. First, seven major elements of BRT are presented along with their respective features and attributes. Second, the BRT elements are related to attributes of system performance. Finally, the benefits of BRT systems are discussed. This order of the discussion suggests the relationship between BRT elements, system performance and system benefits. BRT systems are constructed by choosing and integrating among BRT elements. The integration of elements improves system performance and improves the experience for customers. Improvements to system performance (in combination with features of BRT elements) generate benefits to transit agencies and communities.

14. SUBJECT TERMS

Bus Rapid Transit, BRT, Transit, Public Transportation, Characteristics

15. NUMBER OF PAGES
410

16. PRICE CODE

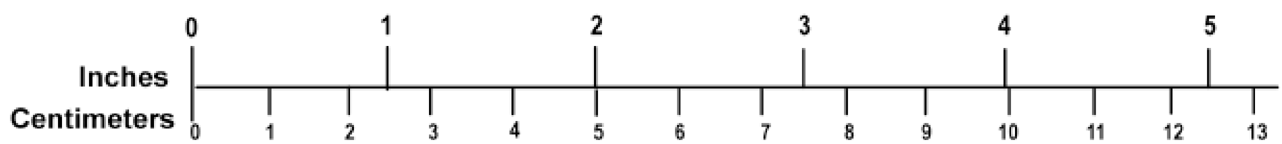
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)

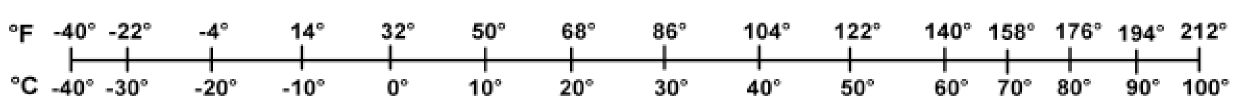
METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC			METRIC TO ENGLISH		
LENGTH (APPROXIMATE)			**LENGTH** (APPROXIMATE)		
1 inch (in)	=	2.5 centimeters (cm)	1 millimeter (mm)	=	0.04 inch (in)
1 foot (ft)	=	30 centimeters (cm)	1 centimeter (cm)	=	0.4 inch (in)
1 yard (yd)	=	0.9 meter (m)	1 meter (m)	=	3.3 feet (ft)
1 mile (mi)	=	1.6 kilometers (km)	1 meter (m)	=	1.1 yards (yd)
			1 kilometer (km)	=	0.6 mile (mi)
AREA (APPROXIMATE)			**AREA** (APPROXIMATE)		
1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)	1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)	1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)	1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)	10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)			
MASS - WEIGHT (APPROXIMATE)			**MASS - WEIGHT** (APPROXIMATE)		
1 ounce (oz)	=	28 grams (gm)	1 gram (gm)	=	0.036 ounce (oz)
1 pound (lb)	=	0.45 kilogram (kg)	1 kilogram (kg)	=	2.2 pounds (lb)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)	1 tonne (t)	=	1,000 kilograms (kg)
				=	1.1 short tons
VOLUME (APPROXIMATE)			**VOLUME** (APPROXIMATE)		
1 teaspoon (tsp)	=	5 milliliters (ml)	1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 tablespoon (tbsp)	=	15 milliliters (ml)	1 liter (l)	=	2.1 pints (pt)
1 fluid ounce (fl oz)	=	30 milliliters (ml)	1 liter (l)	=	1.06 quarts (qt)
1 cup (c)	=	0.24 liter (l)	1 liter (l)	=	0.26 gallon (gal)
1 pint (pt)	=	0.47 liter (l)			
1 quart (qt)	=	0.96 liter (l)			
1 gallon (gal)	=	3.8 liters (l)			
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)	1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)	1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)			**TEMPERATURE** (EXACT)		
[(x-32)(5/9)] °F	=	y °C	[(9/5) y + 32] °C	=	x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

AUTHOR ACKNOWLEDGMENTS

This information document was updated and revised for the United States Department of Transportation's (U.S. DOT) Federal Transit Administration (FTA) by a consortium of organizations led by the National Bus Rapid Transit Institute (NBRTI) at the Center for Urban Transportation Research, University of South Florida. The consortium includes Booz Allen Hamilton, Inc., STV Incorporated, TranSystems, Washington Group International, and Weststart-CALSTART.

Roderick Diaz was the principal editor of this document, with editorial contributions from Lisa Callaghan Jerram, Georges Darido, and Paul Schimek. Contributing authors include Jennifer Flynn, Cheryl Thole, Alasdair Cain, and Victoria Perk of the National Bus Rapid Transit Institute; Richard Laver and Travis Dunn of Booz Allen Hamilton; Pilar Rodriguez and Rosemary Gerty of TranSystems; Paul Schimek of Washington Group International; and Greg Moscoe and Lawrence Wnuk of Weststart-CALSTART. Additional data on international BRT systems was collected by Graham Currie of Monash University and Daniel Haufschild of MRC McLean Hazel. Other contributors include Wendy Teague, report design; Patricia Ball, copy editing; and Pamella Clark and Lisa Ravenscroft, process coordinators. FTA Project Manager was Helen Tann, Transportation Program Specialist.

We are grateful to Renee Haider of the National Transit Institute and to the NBRTI Advisory Board for external review and feedback:

- Joseph Calabrese, Greater Cleveland (Ohio) Regional Transit Authority
- Rex Gephart, Los Angeles County Metropolitan Transportation Authority
- Alan Danaher, Parsons Brinckerhoff
- Cliff Henke, Parsons Brinckerhoff
- Peter Koonce, ITS Consultant
- Herb Levinson, Private Consultant
- Ted Orosz, New York City Transit
- Lurae Stuart, APTA
- Stefano Viggiano, Lane Transit District, Eugene, Oregon
- Bill Vincent, Breakthrough Technologies
- David Wohlwill, Port Authority of Allegheny County, Pennsylvania
- Nigel Wilson, MIT
- Sam Zimmerman, World Bank

TABLE OF CONTENTS

LIST OF EXHIBITS

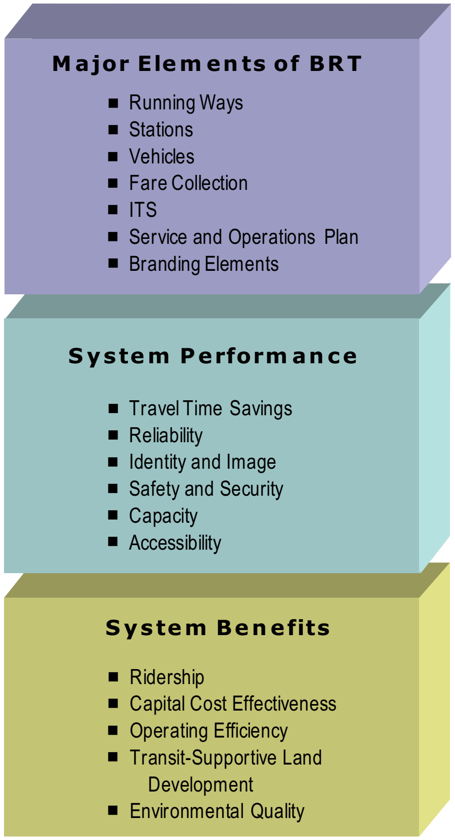
EXECUTIVE SUMMARY

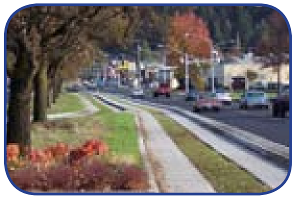
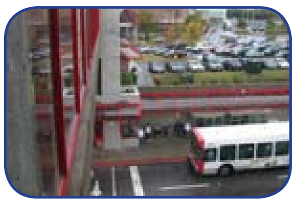
The updated "Characteristics of Bus Rapid Transit for Decision-Making" (2009) (CBRT) report was prepared to provide transportation planners and decision makers with basic information and data to support the development and evaluation of bus rapid transit concepts as one of many options during alternatives analyses and subsequent project planning. This report provides information on BRT systems in a single, easy-to-use reference tool for transportation planners in selecting from the large array of BRT elements and integrating them into comprehensive systems.

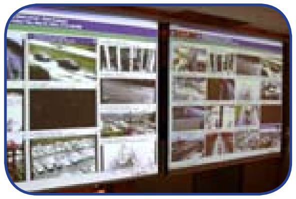
The CBRT report explores BRT through a progression of three different perspectives. First, seven major elements of BRT are presented along with their respective features and attributes. Second, the BRT elements are related to attributes of system performance. Finally, the benefits of BRT systems are discussed. This order of the discussion suggests the relationship between BRT elements, system performance, and system benefits. BRT systems are constructed by choosing and integrating among BRT elements. The integration of elements improves system performance and the experience for customers. Improvements to system performance (in combination with features of BRT elements) generate benefits to transit agencies and communities.

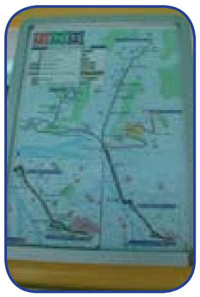
Experience with BRT Elements

Experience in the United States suggests that implementation of more complex BRT system elements is just beginning. Implementation of running ways, stations, and vehicles suggest a wide variety of applications. Some of the more quickly implemented projects demonstrated the least amount of investment in BRT system elements.



BRT ELEMENT	EXPERIENCE IN THE UNITED STATES	INTERNATIONAL EXPERIENCE
Running Way - Running Way Segregation - Running Way Marking - Guidance (Lateral) 	• BRT systems in the U.S. have incorporated all types of running ways —mixed flow arterial (Los Angeles, Oakland, Kansas City), mixed flow freeway (Phoenix), dedicated arterial lanes (Boston, Orlando), at-grade transitways (Miami, Eugene), and fully grade-separated surface transitways (Pittsburgh), and subways (Seattle, Boston). • Mechanical guidance features have been incorporated into a few BRT systems (Eugene, Cleveland). The only application of non-mechanical running way guidance was the precision docking for Las Vegas MAX with optical guidance, which has since been deactivated. • Use of running way markings to differentiate BRT running ways and articulated brand identity was rare.	• Use of exclusive running ways, both arterial bus lanes in transitways is widespread across new BRT applications in Europe, Asia, Australia, and the Americas. • Use of running way guidance is evident with mostly mechanical guidance applications (Adelaide, Amsterdam, Leeds), although optical guidance applications (Rouen) are functional. • Physical barriers such as curbs and raised markers are evident in some especially-congested corridors in Latin America and Asia. Colored lane markings are used in a few cases (e.g., Auckland, London, Nagoya, Sydney, Utrecht)
Stations - Station Type - Platform Height - Platform Layout - Passing Capability - Station Access 	• The level of station design correlates strongly with the level of running way segregation. Systems with designated lanes on arterials or segregated transitways had stations with higher sophistication and more amenities. • The use of level boarding has grown in the U.S. following the example of Las Vegas MAX, new applications of raised curbs in Eugene, and near-level boarding in Cleveland. No uniform approach to the vehicle platform interface has yet emerged. • Real-time schedule and/or vehicle arrival information and communications infrastructure such as public telephones and emergency telephones are starting to be installed in systems (Los Angeles Orange Line).	• As the use of exclusive running ways is more common among international BRT systems, more elaborate station types are used. • Enclosed stations are common among Latin American systems.
Vehicles - Vehicle Configuration - Aesthetic Enhancement - Passenger Circulation Enhancement - Propulsion 	• Early BRT systems used standard vehicles that were often identical to the rest of a particular agency's fleet. Systems such as Los Angeles' Metro Rapid, AC Transit's Rapid Bus, and Boston's Silver Line, are phasing in operation of 60-ft articulated buses as demand grows. • The use of vehicle configurations or aesthetic enhancements to differentiate BRT is gaining momentum. In addition to differentiated liveries and logos, agencies are procuring stylized and specialized BRT vehicles. Las Vegas represents the first use of a specialized BRT vehicle in the U.S. Other systems (Cleveland, Eugene, Los Angeles Orange Line, Oakland) are implementing stylized vehicles in both articulated and standard sizes.	• Use of stylized vehicles is widespread in European and Latin American BRT systems, although conventional bus configurations are still the norm worldwide. • A few systems use bi-articulated buses on trunk lines in Latin America (Curitiba, Bogotá) and Europe (Eindhoven, Utrecht, and Caen). • High-floor vehicles are common among Latin American systems. Low-floor vehicles are becoming more widely applied elsewhere throughout the world.

BRT ELEMENT	EXPERIENCE IN THE UNITED STATES	INTERNATIONAL EXPERIENCE
Fare Collection - Fare Collection Process - Fare Transaction Media - Fare Structure 	• Alternate fare collection processes are rare in the U.S. Use of proof-of-payment is growing (Las Vegas MAX system, Los Angeles Orange Line, Cleveland Health Line). Variations on proof-of-payment such as free downtown zones and pay-on-exit are used in Orlando, Seattle, and Pittsburgh • Electronic fare collection using magnetic-stripe cards or smart cards is slowly being incorporated into BRT systems, but as part of agency-wide implementation rather than BRT-specific implementation. Smart cards are more common than other forms of electronic fare collection.	• Pre-paid fare collection is the norm among BRT systems in Latin America (Bogotá, Curitiba, Quito, Guayaquil) and new systems in China (Beijing, Hangzhou). • Some proof-of-payment examples are evident in Europe. • Pay-on-board systems are still fairly common. A few systems (Eindhoven) have incorporated ticket vending machines on board vehicles. • Some Australian systems (Adelaide, Brisbane, Sydney) use magnetic stripe tickets. The use of smart cards is growing across a wide variety of BRT systems (Bogotá, Pereira, and Guayaquil in Colombia; Beijing, Hangzhou, and Kunming in China).
Intelligent Transportation Systems - Vehicle Prioritization - Driver Assist and Automation Technology - Operations Management Technology - Passenger Information - Safety and Security Technology - Support Technologies 	• The most common ITS applications include Transit Signal Priority, Automatic Vehicle Location Systems, Automated Scheduling and Dispatch Systems, and Real-Time Traveler Information at Stations and on Vehicles. • Installation of security systems such as emergency telephones at stations and closed circuit video monitoring is rare, but increasing as newer, more comprehensive systems are implemented.	• As in the U.S., Automatic Vehicle Location and Transit Signal Priority, and Real-Time Traveler Information are the most commonly implemented ITS systems. • Electronic guidance systems have been implemented in only a few cases (Rouen, Eindhoven).

BRT ELEMENT	EXPERIENCE IN THE UNITED STATES	INTERNATIONAL EXPERIENCE
Service and Operating Plans - Route Length - Route Structure - Service Span - Frequency of Service - Station Spacing - Method of Schedule Control 	• Implementations of BRT generally followed principles of greater spacing between stations, all-day service spans, and frequent service. • Systems that use exclusive transitways (Miami-Dade's at-grade South Busway and Pittsburgh's grade-separated transitways) are operated with integrated networks of routes that include routes that serve all stops and a variety of feeders and expresses with integrated off-line and line-haul operation. • Recent examples of systems with exclusive transitways (Los Angeles Orange Line, Boston Silver Line, Eugene EmX, Cleveland Health Line).	• Exclusive transitways with grade-separated operation host integrated networks of routes. (Ottawa, Brisbane, Bogotá). • Many of the Latin American systems demonstrate integrated trunk and feeder route networks (Curitiba, Quito, Bogotá, Pereira, Quito, Guaya-quil). • Some systems in arterial streets have overlapping BRT service patterns (Caen, Rouen), while most have either one single BRT route pattern or one BRT route operating parallel with a local service.
Branding Elements - Marketing Classification of BRT - Branding Devices 	• Most newly-launched BRT systems have been consciously marketed as distinct from local transit services with distinct BRT brands. • Use of brand names, logos, and colors is widespread.	• Especially in the context of developing countries, implementation of BRT as a distinct brand has been used as a tool to reform and regulate the bus industries and simplify the service offerings perceived by the public (many cases in Brazil, Colombia, and China). • Use of brand names, logos, and colors is widespread. Use of differenti-ated colors for other types of bus service is common in Latin America. • In some cases, it is common for the running way facility and stations to be branded, while some routes that serve them are designated like other routes in the system (Ottawa, Brisbane).

Experience with BRT System Performance

System performance for BRT systems is assessed according to six key attributes —travel time, reliability, identity and image, safety and security, capacity, and accessibility. Each of the BRT system elements has different effects on system performance.

BRT elements have different impacts on system performance attributes. The most direct impacts are summarized here.

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
RUNNING WAY						
Running Way Location	×	×	×	×	×	×
Level of Transit Priority	×	×	×	×	×	
Running Way Marking	×	×	×	×		
Running Way Guidance	×	×	×	×		
STATIONS						
Station Location and Type	×		×	×	×	
Passenger Amenities			×	×		
Curb Design	×	×	×	×	×	×
Platform Layout	×	×	×		×	×
Passing Capability	×	×			×	
Station Access			×	×		×
VEHICLES						
Vehicle Configuration	×	×	×	×	×	×
Aesthetic Enhancement			×	×		
Passenger Circulation Enhancement	×	×	×	×	×	×
Propulsion Systems	×		×			
FARE COLLECTION						
Fare Collection Process	×	×	×		×	×
Fare Media / Payment Options	×	×	×	×	×	
Fare Structure	×		×		×	
INTELLIGENT TRANSPORTATION SYSTEMS						
Vehicle Prioritization	×	×	×		×	
Intelligent Vehicle Systems	×	×	×	×	×	
Operations Management Systems	×	×		×	×	
Passenger Information Systems	×	×	×	×		
Safety and Security Systems				×		
SERVICE AND OPERATING PLANS						
Route Length		×				
Route Structure	×		×			×
Span of Service		×				
Frequency of Service	×	×		×	×	
Station Spacing	×	×				×
BRANDING ELEMENTS						
Marketing Classification of BRT Service			×			
Branding Devices			×			

BRT system performance can be assessed based on the experience of at least 40 systems across the United States and the world. The experience suggests that there are concrete improvements to travel time, reliability, and capacity as well as perceptions of improvements in safety and security and image and identity.

Travel Time

With respect to total BRT travel times, BRT projects with more exclusive running ways generally experienced the greatest travel time savings compared to the local bus route. Exclusive transitway projects operated at speeds (including stops) between 20 and 30 miles per hour (travel time rate between 2 to 3 minutes per mile), with even higher speeds demonstrated in along the portions of the routes in exclusive sections. Arterial BRT projects in mixed-flow traffic or designated lanes operated between 12 and 18 miles per hour (between 3.5 and 5 minutes per mile). Demonstration of low dwell times per passenger is most evident where there are high passenger loads, pre-paid fare collection systems, and all-door level boarding (such as in many of the Latin American systems.)

Reliability

Performance in reliability also demonstrated a similar pattern as travel times. As expected, systems with more exclusive transitways demonstrated the most reliability and the least schedule variability and bunching. The ability to track reliability changes has been limited by the fact that most transit agencies do not regularly measure this performance attribute. Passenger surveys, however, indicate that reliability is important for attracting and retaining passengers and that passengers do respond to more reliable services. New automated vehicle location systems may allow for the objective and conclusive measurement of reliability.

Image and Identity

Most BRT systems in the United States and internationally are successfully marketed as distinct brands of service through a combination of high quality service attributes and explicit use of branding devices. Performance in achieving a distinct brand identity for BRT has been measured by in-depth passenger surveys. The more successful BRT systems have been able to achieve a distinct identity and position in the respective region's family of transit services. BRT passengers generally had higher customer satisfaction and rated service quality higher for BRT systems than for their parallel local transit services.

Safety and Security

Data measuring the difference in safety and security of BRT systems as compared with the rest of the respective region's transit system are rarely collected. Drawing conclusions about the efficacy of BRT elements in promoting safety and security is therefore premature. Data from Pittsburgh suggest that BRT operations on exclusive transitways have significantly fewer accidents per unit (vehicle mile or vehicle hour) of service than conventional local transit operations in mixed traffic. Customer perceptions of "personal safety" or security reveal that customers perceive BRT systems to be safer than the rest of the transit system. The experiences of a few newly-launched systems suggest the need for significant attention to collision prevention where buses intersect with general automobile traffic in the first few months of operation.

Capacity

For virtually all BRT systems implemented in the United States, capacity has not been an issue. To date, none of them have been operated at their maximum capacity. On all systems, there is significant room to expand operated capacity by operating larger vehicles, higher frequencies, or both. International cases, especially in Latin America and Asia, demonstrate abilities to host significant loads of passengers with faster travel times and reliability.

Experience with BRT System Benefits

The benefits of BRT system implementation are now being felt. While the most tangible benefit is additional ridership, cost effectiveness and operating efficiencies as well as increases in transit-supportive land development and environmental quality are also closely linked to the implementation of BRT systems.

Ridership

There have been significant increases in transit ridership in virtually all corridors where BRT has been implemented. In the United States, though much of the ridership increases have come from passengers formerly using parallel service in other corridors, passenger surveys have revealed that many trips are new to transit, either by individuals who used to drive or be driven, or individuals who used to walk, or by individuals who take advantage of BRT's improved level of service to make trips that were not made previously.

Aggregate analyses of ridership survey results suggest that the ridership increases due to BRT implementation exceed those that would be expected as the result of simple level of service improvements. This implies that the identity and passenger information advantages of BRT are attractive to potential BRT customers. Ridership gains of between 5 and 25 percent are common. Significantly greater gains, such as 85 percent in Boston's Silver Line, represent the potential for BRT.

Ridership gains are evident internationally, as well. Analysis of a few cases shows that mode shift can be just as dramatic. In many areas, system efficiency and reliability have created opportunities for more accessibility, thereby attracting passengers to the systems.

Capital Cost Effectiveness

BRT demonstrates relatively low capital costs per mile of investment. Recently-implemented BRT systems include a wide range of system types with a wide range of costs, from less capital-intensive investments on arterial streets to newly-opened exclusive transitways, which are more capital intensive. Depending on the operating environment, BRT systems are able to achieve service quality improvements (such as travel time savings of 15 to 25 percent and increases in reliability) and ridership gains that compare favorably to the capital costs and the short amount of time to implement BRT systems. Furthermore, BRT systems are able to operate with lower ratios of vehicles compared to total passengers.

Operating Cost Efficiency

BRT systems are able to introduce higher operating efficiency and service productivity for transit systems that incorporate them. Experience shows that when BRT is introduced into corridors and passengers are allowed to choose BRT service, corridor performance indicators (such as passengers per revenue hour, subsidy per passenger mile, and subsidy per passenger) improve. Furthermore, travel time savings and higher reliability enables transit agencies to operate more vehicle miles of service from each vehicle hour operated. In international cases, BRT implementation has improved overall system efficiency by reforming transit institutions and local transit industries and tying transit regulation to system performance.

Transit-Supportive Land Development

In places where there has been significant investment in transit infrastructure and related streetscape improvements (e.g., Boston, Pittsburgh, Ottawa, and Vancouver), there have been significant positive development effects. In some cases, the development has been adjacent to the transit facility, while in other places the development has been integrated with the transit stations. Cases such as Curitiba in Brazil demonstrate the ability for BRT to shape urban development. Even some documentation in cities such as Bogotá suggest that property values are positively affected by accessibility provided by BRT systems. Experience is not yet widespread enough to draw conclusions on the factors that would result in even greater development benefits from BRT investment, although the general principle that good transit and transit-supportive land uses are mutually reinforcing holds.

Environmental Quality

Documentation of the environmental impacts of BRT systems is rare. Experience does show that there is improvement to environmental quality due to a number of factors. Ridership gains suggest that some former automobile users are using transit as a result of BRT implementation. Transit agencies are serving passengers with fewer hours of operation, potential reducing emissions. Most important, transit agencies are adopting vehicles with alternative fuels, propulsion systems, and pollutant emissions controls. Implementation of BRT systems both within the United States and internationally shows that efforts to improve emissions for vehicles in the BRT system often result in reductions in emissions systemwide.

Progress with Documenting BRT Experience

While BRT systems have been under development for decades, of BRT systems has seen dramatic growth over the past decade, both in the United States and throughout the world. BRT as of 2008 represents significant progress and demonstrates the impact of the growing body of knowledge of BRT systems both in the United States and throughout the world. BRT systems are now being integrated much more consciously and comprehensively and in ways that are more meaningful and understandable for passengers and non-passengers alike. These integrated systems are being implemented as focal points to improvements to transit within their respective service areas. As such, BRT planning efforts demonstrate attention to a broader array of objectives. In addition to improving travel time and capacity, other objectives such as reliability, safety and security, and identity and image are motivating the integration of additional elements such as advanced vehicles and more elaborate stations into BRT systems. Ridership gains of between 5 and 25 percent are common. Furthermore, benefits such as transit-supportive development, environmental quality, capital cost effectiveness, and operating efficiency are being realized and demonstrated more broadly and concretely.

Many of the currently-implemented systems demonstrate the value of BRT system flexibility. Systems have been launched with small packages of BRT elements. Once success has been demonstrated, more features are added to bring even more benefits to the BRT system. Some arterial BRT systems are now planning for exclusive lanes. As technology develops, more BRT systems are incorporating electronic fare collection and Intelligent Transportation Systems. Changes to vehicle technology, spurred by greater attention to environmental impacts (both local pollutants and greenhouse gases) and new regulations, are also being incorporated into BRT systems.

Documenting these projects and extended experience with existing projects in future editions of "Characteristics of Bus Rapid Transit for Decision-Making" will help to demonstrate the longer-term performance and benefits of BRT.

NEED AND PURPOSE

One of the Federal Transit Administration's (FTA) objectives is to provide local and state officials with the information they need to make informed transit investment decisions. With this objective in mind, "Characteristics of Bus Rapid Transit for Decision-Making" (CBRT) was prepared. It provides transportation planners and decision-makers with basic information and data to support the development and evaluation of bus rapid transit (BRT) concepts as one of many options during alternatives analyses and subsequent project planning. This report describes the physical, operational, cost, performance, and potential benefits of BRT's elements, both individually and combined as integrated systems. Its intended audience includes urban transportation professionals and officials involved in developing and evaluating high performance transit systems, of which BRT is one alternative.

What is BRT?

"BRT Implementation Guidelines" (Levinson et al. 2003) defines BRT as:

> A flexible, high performance rapid transit mode that combines a variety of physical, operating and system elements into a permanently integrated system with a quality image and unique identity.

This definition highlights BRT's flexibility and the fact that it encompasses a wide variety of applications, each one tailored to a particular set of travel markets and physical environments. BRT's flexibility derives from the fact that BRT vehicles (e.g., buses, specialized BRT vehicles) can travel anywhere there is pavement and the fact that BRT's basic service unit, a single vehicle, is relatively small compared to train-based rapid transit modes. A given BRT corridor application might encompass route segments where vehicles operate both in mixed traffic and on a dedicated, fully grade-separated transitway with major stations. BRT is an integrated system that is designated to improve the speed, reliability, and identity of bus transit.

BRT applications can combine various route segments such as the above to provide a single-seat, no-transfer service that maximizes customer convenience. Unlike other rapid transit modes where basic route alignment and station locations are constrained by right-of-way availability, BRT can be tailored to the unique origin and destination patterns of a given corridor's travel market. As the spatial nature of transit demand changes, BRT systems can adapt to these dynamic conditions.

Many of the concepts at the heart of BRT have been in use for decades. Dedicated transitways/busways, limited-stop and express services, and exclusive bus lanes have become part of the transit planning vocabulary because they have enhanced speed and reliability and thus encouraged transit usage; however, there is uncertainty among elected officials and even some transit professionals about what BRT is and how it differs from conventional bus services and systems. This question is difficult to answer, in part because the options available for each BRT element are so extensive that there is an infinite variety of integrated BRT systems. BRT's inherent flexibility means that no two BRT systems will look exactly the same within a given region, let alone between two different metropolitan areas.

Fortunately, there is an extensive body of information and data describing each of BRT's elements and a growing body of literature on the cumulative impacts of packaging multiple elements into integrated BRT systems. This report combines both types of information in a single, easy-to-use reference tool for transportation planners generating evaluation criteria for use in selecting from the large array of BRT elements and integrating them into comprehensive systems. In addition, since the publication of the first edition of "Characteristics of Bus Rapid Transit for Decision-Making" in 2004, the body of experience with BRT both in the United States and throughout the world has grown. Information from more of these systems is presented in this edition of CBRT.

BRT IN THE TRANSPORTATION PLANNING PROCESS

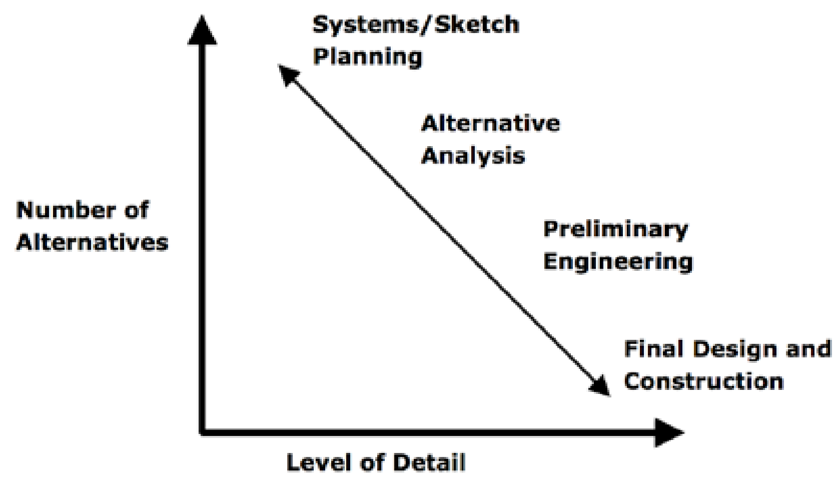
Understanding BRT's capabilities is important for assessing its performance and potential benefits during an alternatives analysis. The Federal Transit Act requires that all requests for capital assistance for New Start funds be preceded by an alternatives analysis where a full range of feasible, potentially cost-effective alternatives for addressing specific transportation needs are objectively and transparently evaluated. Despite the fact that BRT is a bona fide rapid transit concept, many local planning efforts often do not have complete information regarding the following characteristics of BRT systems:

- physical and operating characteristics
- ridership attraction
- capital, operating, and maintenance costs
- performance in terms of speed, reliability and other measures
- air, noise, and other environmental impacts
- ability to induce sustainable, transit-oriented land uses

Unfamiliarity with these characteristics of BRT affects the ability of planning to support completely informed decision-making about investments.

In addition to the need for better information about BRT for use in alternatives analyses, there is also a need for information on BRT for less complex, "first cut" sketch planning exercises, where an initial list of viable, potentially desirable alternatives is developed. Exhibit 1-1 illustrates the relationship of the number of alternatives considered during systems/sketch planning, alternatives analysis, preliminary engineering, and other planning and project development steps to the level of design detail utilized.

Exhibit 1-1: Transit Investment Planning and Project Development Process



Early in the planning process, there are many alternatives available to solve a specific transportation need. Because of resource constraints, all alternatives cannot be exhaustively analyzed in detail at all planning stages. Once the universe of potentially-feasible options has been narrowed down to a small number through the sketch planning process, a more detailed analysis can be undertaken. Initially, sketch planning techniques are used to establish the range of alternatives that meet screening criteria, ruling out those alternatives determined to have "fatal flaws" or with significantly lower performance than others. In essence, it sets the agenda for subsequent and more detailed alternatives analyses.

Although sketch planning does not provide the level of detail necessary in the alternatives analysis process, it does require planners to grasp the universe of potential alternatives and have access to accurate and balanced information about the ability of each alternative to meet a broad set of performance, operational, and cost objectives.

After a detailed alternatives analysis in support of major investment decision-making is performed (e.g., to support a subsequent FTA New Starts funding application), only one recommended alternative defined in terms of mode, systems concept, and general alignment will remain. At this stage, the project can advance to preliminary engineering, which uses much more detailed engineering and operations analysis and provides a complete description of the given alternative. Preliminary engineering is followed by final design and construction.

INTENDED USE OF THE CBRT REPORT

The purpose of the CBRT report is to provide a useful reference for transit and transportation planning officials involved in both sketch planning and detailed alternatives analyses. The report provides a detailed overview of BRT's seven basic elements and the costs and benefits of combining them in different ways. It provides useful information to planners and decision-makers on each element and how the elements might be packaged into an integrated system to produce the maximum benefits. The report is meant to provide a description of the possibilities that BRT provides and the experience of various BRT systems around the world. As a description of practice, the CBRT report is not intended to prescribe solutions for local communities interested in implementing BRT. That task is left to the many industry guidance documents.

The data provided in this report also can be used to assess the reasonableness of cost estimates and ridership forecasts prepared as part of FTA alternative analyses through detailed engineering studies, ridership projections, and cost modeling. While the report does not contain the data needed to develop operating and maintenance cost models, it does provide information that can be used as a "baseline" to assess the reasonableness of forecasts produced from these requirements. In cases where more detailed alternatives development and analysis are needed before decision-makers can reach closure, the CBRT report provides practitioners with benchmark data to assess the reasonability and reliability of the benefits, costs, and impact assessment results produced by more detailed analysis tools such as travel forecasting, multi-modal traffic simulation, and fully-allocated or incremental operating and maintenance cost models.

Exhibit 1-2 summarizes the potential applications of the CBRT report in the planning and project development process described above. Of the three major steps described in Exhibit 1-2, the CBRT is most relevant to Systems Planning and Alternatives Analysis.

Exhibit 1-2: Characteristics of BRT in Project Planning and Development

	Screening of Alternatives Systems Planning/ Sketch Planning	Alternatives Analysis	Preliminary Engineering
Task	Identification and screening of broadly-defined system package concepts for refinement and analysis	Definition of alternatives at both BRT element and system's package level; check reasonability of analysis results	Detailed definition of each element in selected system package; assessment of reasonability of specifications and cost estimates, by element
Level of Detail of Information	Cost, benefit, and impact estimates at sketch planning level of detail	More accurate estimates of costs, benefits, and impacts for system alternatives	Detailed cost, performance, and impact estimates to take into final design and implementation
Outcome	Alternatives for further refinement and/or analysis	Single system's package of BRT elements to bring into Project Development / Preliminary Engineering	Detailed definition of project to take into Final Design/implementation

Note that the emphasis of the CBRT report is on front-end transit planning and development, where analytical detail is not as critical to decision-making as having knowledge of viable project alternatives. At the beginning of the planning process, the CBRT report helps senior planners and decision-makers identify the range of possibilities at both the individual element and systems level as quickly as possible. For less intensive projects, such as situations where a set of simple bus corridor improvements may not require a full alternatives analysis, the CBRT's usefulness is focused on the Screening and Systems Planning phase. More involved projects, such as those in the United States that might apply for Small Starts or Very Small Starts funding, do undertake an alternatives analysis and can therefore continue to refer to the CBRT during that phase of project development.

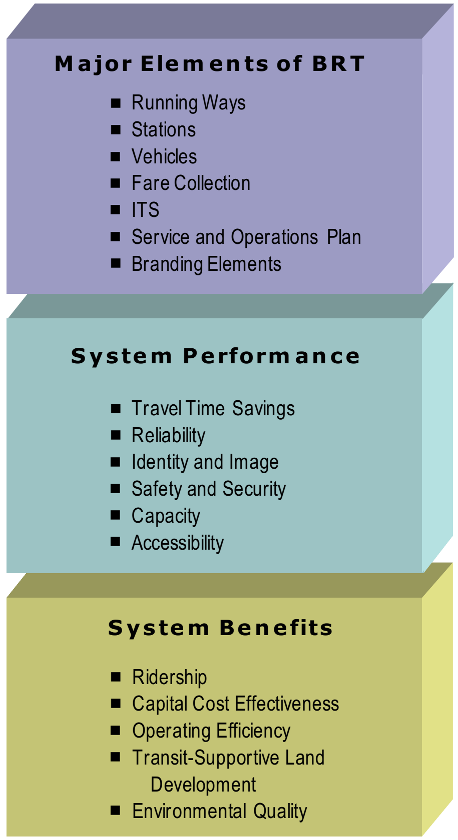
The CBRT report also provides aggregate physical, operational, cost, and performance information useful in reducing the number to a more manageable subset for subsequent analysis or implementation, depending on the situation. For more detailed implementation guidance for later and more detailed phases of project design, transportation planners and BRT system designers are encouraged to use the relevant industry standards and codes and the many implementation guidelines that have been developed to support BRT and the bus industry, such as:

- "TCRP Report 90: Bus Rapid Transit (Volume 1: Case Studies and Volume 2: Implementation Guidelines)" (TRB 2003)
- "TCRP Report 118: Bus Rapid Transit Practitioner's Guide" (including a discussion of cost and effectiveness of selected BRT components) (TRB 2007)
- "Transit Capacity and Quality of Service Manual" (TRB 2004)
- "Highway Capacity Manual" (TRB 2000)
- "Standard Bus Procurement Guidelines" (APTA, 1997 through 2002)
- "BRT Vehicle Characteristics" (FTA 2001)
- "ITS Enhanced Bus Rapid Transit" (FTA 2003)
- "Standards for Bus Rapid Transit" (APTA beginning in 2008 and continuing)

STRUCTURE AND CONTENT OF CBRT

The core of the CBRT report is organized into three related topic areas, as illustrated by Exhibit 1-3.

Exhibit 1-3: CBRT Topic Areas



- ***Major Elements of BRT*** (Chapter 2)—This chapter describes seven major BRT elements, including detailed discussion of the options and associated costs for each—Running Ways, Stations, Vehicles, Fare Collection, Intelligent Transportation Systems, Service Plans, and Branding Elements. A discussion on integrating these elements and developing a branding scheme around them completes the chapter.

- ***BRT Elements and System Performance*** (Chapter 3)—This chapter discusses how each BRT element contributes to transit objectives, including reducing travel times, improving reliability, providing identity and a quality image, improving safety and security, increasing capacity, and enhancing accessibility.
- ***BRT System Benefits*** (Chapter 4)—This chapter describes some of the most important benefits of integrated BRT systems in terms of ridership, economic development, and environmental mitigation. The chapter also includes an assessment of the impact of BRT system implementation on two important categories of transit system performance—capital cost-effectiveness and operating efficiency.

The three-part conceptual framework describes the function of each element as a part of an integrated package and identifies the functional interface between related elements in achieving specific performance objectives. For example, the effectiveness of certain elements is either magnified or nullified when implemented in combination with other elements. Functional interface issues like these will be carefully identified in Chapters 2 and 3.

Accordingly, information on performance measures and outcomes (e.g., travel time, capacity, operating and maintenance costs, ridership) will be included to describe various BRT systems.

The remainder of the report synthesizes the information presented in Chapters 2, 3, and 4 and presents findings and conclusions.

- Chapter 5 provides a summary of BRT experience. It provides a summary of how elements have been implemented, what performance objectives have been achieved, and what benefits are generated. Chapter 5 also describes how the CBRT report will be sustained as a vital source of information on BRT.
- Appendices include a bibliography of useful references, glossary of terms related to BRT, summaries of the BRT projects, and BRT system details and specifications.

NEW CONTENT IN CBRT 2008

The 2008 edition of the CBRT report incorporates a number of revisions and additions since the original 2004 edition. The structure of the report essentially remains the same with the same five chapters framing the discussion. Throughout the document, more information from BRT systems is presented to reflect the growing experience with BRT systems and their improved performance and the benefits they generate for transit systems and their communities:

- Updated and more detailed data and information on BRT systems that were presented in the 2004 edition, including evaluations of systems in Boston, Honolulu, Oakland, Las Vegas, and Los Angeles
- Information from systems that have begun operations in the United States
- Information from international BRT systems, including the results of data collection efforts in Australia, Asia, Europe, and Latin America. While not comprehensive, this data collection effort extends the exchange of information of BRT systems across the globe, creating a fuller picture of the relationships explored in the report

This information is presented throughout the discussion in Chapters 2, 3, and 4. Other changes in the document include:

Chapter 2

- Re-organized and updated discussion of BRT elements
- Additional discussion of "Reasons to Implement" and "Considerations/Requirements" in the discussion of each BRT element
- Inclusion of branding elements as a major element of BRT
- Revised discussion of BRT system interfaces, acknowledging interfaces with more than two elements

Chapters 3 and 4

- Updated discussions of performance attributes and benefits
- More consistent structure within the discussion of each performance attribute and each benefit
- Addition of accessibility as a performance attribute
- New case studies (system performance profiles), research summaries, and data analysis of data relating BRT elements and performance and benefits
- More complete discussions and explorations of the relationship between BRT and benefits in Chapter 4

MAJOR ELEMENTS OF BRT

As described in Chapter 1, Bus Rapid Transit is a flexible, permanently-integrated package of rapid transit elements with a quality image and distinct identity. This chapter describes the characteristics, range of options, relative costs, and a variety of other critical planning parameters for the following seven major BRT elements.

- ***Running Ways***—Running ways significantly impact travel speeds, reliability, and identity. Options range from general traffic lanes to fully-grade-separated BRT transitways.
- ***Stations***—Stations, as the entry point to the system, are the single most important customer interface, affecting accessibility, reliability, comfort, safety, and security, as well as dwell times and system image. BRT station options vary from simple stops with basic shelters to complex stations and intermodal terminals with many amenities.
- ***Vehicles***—BRT systems can utilize a wide range of vehicles, from standard buses to specialized vehicles. Options vary in terms of size, propulsion system, design, internal configuration, and horizontal/longitudinal control, all of which impact system performance, capacity, and service quality. Aesthetics, both internal and external, also are important for establishing and reinforcing the brand identity of the system.
- ***Fare Collection***—Fare collection affects customer convenience and accessibility, as well as dwell times, service reliability, and passenger security. Options range from traditional pay-on-board methods to pre-payment with electronic fare media (e.g., smart cards).
- ***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, safety, and security. ITS options

include vehicle priority, operations and maintenance management, operator communications, real-time passenger information, and safety and security systems.

- ***Service and Operations Plan***—Designing a service plan that meets the needs of the population and employment centers in the service area and matches the demand for service is a key step in defining a BRT system. How it is designed can impact system capacity, service reliability, and travel times, including wait and transfer times.
- ***Branding Elements***—Branding Elements tie all of the various physical and service elements of BRT systems together are Branding elements. The approach to branding BRT systems packages all of the elements into a cohesive system and communicates the value of BRT elements to the traveling public.

The aim of this chapter is to describe the specific discrete options available for each BRT element. Greater detail on the performance of these elements as part of comprehensive systems and in terms of how they relate to specific BRT objectives will be presented in Chapter 3.

Sections 2.1 through 2.7 discuss each element according to the following structure:

Description: A brief description of each element with:

- ***Role of the element***—a description of the role of each element of BRT systems
- ***Element characteristics***—a discussion of the primary characteristics of each element

Options: Various options for each element characteristic, with images and costs.

Implementation Issues: Two types of issues will be presented with each issue—those relevant during Project Development (planning, procurement, design, and construction) and those relevant during Operations (after commencement of service).

Summary of Experience: Real-world information on implementation of the element in BRT systems.

Since each of these elements must be combined in an integrated fashion to maximize the impact of the investment, the last section, Section 2.8, explores several different interfaces or packages of BRT elements. This discussion shows how the integration of certain BRT elements contributes to the optimal function, performance, and increased benefits.

RUNNING WAY

Description

Role of the Running Way in BRT

The running way defines where BRT vehicles travel. It is analogous to tracks in a rail transit system. How running ways are incorporated into a BRT system is the major defining factor for the entire BRT system. Running ways are the most critical element in determining the speed and reliability of BRT services. Running ways can be the most significant cost item in the entire BRT system. Finally, as the BRT element most visible to the general public, including both existing and potential customers, running ways can have a significant impact on the image and identity of the system.

Characteristics of Running Way

There are three primary BRT running way characteristics:

1. ***Running Way Type***—The running way type is the primary parameter when planning running ways. It is defined by two sub-characteristics – the right-of-way location and the level of running way priority. These two sub-characteristics represent the two stages of decision-making when defining the running way type.

   Right-of-Way Location—BRT can operate "on-street," using a public right-of-way generally open to all traffic, including pedestrians and bicyclists, and providing access to all adjacent land uses. BRT can also operate "off-street," using an express right-of-way open to restricted types of traffic and providing access to adjacent land uses only at designated areas. On-street rights-of-way are generally never owned or operated by transit operators. Off-street rights-of-way, which include expressways (open to all traffic) and transitways (for transit vehicles only), may be owned and operated by a public transit authority or a highway authority but usually not by local governments.

   Level of Running Way Priority—Based on the right-of-way location, the level of priority and infrastructure investment defines how BRT vehicles operate with respect to other traffic and vehicles. Together, the right-of-way Location and the level of running way priority define the running way type.

2. ***Running Way Marking***—Just as a track indicates where a train travels for rail transit passengers and the community, treatments or markings to differentiate a running way can effectively convey where a BRT service operates. Running ways for buses can be differentiated through a number of techniques, including pavement markings, lane delineators, alternate pavement texture, and alternate pavement color.

3. ***Running Way Guidance***—BRT running ways can be designed to accommodate vehicles equipped with automatic lateral guidance, a feature that controls the side-to-side movement of vehicles along the running way, similar to how a track defines where a train operates. Some BRT systems incorporate a form of lateral guidance to meet one or more of a variety of objectives, including reducing right-of-way width requirements and curvature, providing a smoother ride, and facilitating precision docking at stations, allowing no-step boarding and alighting. Technology for guidance varies, and can be mechanical, electro-magnetic, or optical.

Running Way Options

Running Way Type

BRT systems are largely defined by the running way type. BRT's flexibility means that a single BRT route can operate on several different segments of different running way types. Two sub-characteristics define the running way type—right-of-way location and the level of running way priority.

The various running way types are described below, in two groupings that correspond to the right-of-way location—on-street and off-street.

On-Street Running Way Types

Conventional streets and roads open to all traffic are the most common type of running way used by bus transit. The road system provides universal access to most locations, as buses can operate on all but the narrowest streets. Operating on ordinary streets provides flexibility in terms of providing service where it is needed.

On-Street Running Way Types

Mixed-Flow Lanes

Mixed-flow lanes represent the simplest and most basic type of operation for bus service. BRT vehicles operate with other traffic (automobiles, trucks, and other buses) on existing roads. Most rubber-tired urban transit service operates on mixed flow lanes..

COST: $0. Operation on mixed-flow lanes typically does not cost transit agencies. Cost for operation and maintenance are typically borne by the municipality that owns the roadway.

Bus in Pittsburgh at a local stop

REASONS TO IMPLEMENT

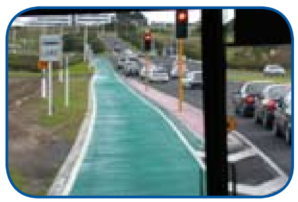
- Use of mixed-flow lanes is common when constraints limit the application of additional priority measures.
- Often, implementation of BRT service on mixed-flow lanes is launched as an interim step while priority measures are being planned or constructed or when congestion does not require priority measures.

CONSIDERATIONS/ REQUIREMENTS

- Operation in mixed-flow lanes often still requires coordination with local street departments or authorities to define traffic control or required pavement enhancement.

Mixed Flow Lanes with Queue Jumpers

A queue jumper is a lane on an approach to a traffic bottleneck location that is reserved for buses or serves a bus-only movement. Bottleneck locations are usually intersections but can be non-intersection locations such as in advance of a narrower section of roadway (e.g., a bridge or a narrow urban street). There are at least two widely-used categories of queue jumpers—those with a physical lane only and those that are integrated with traffic signals.



Painted bus lanes separated from mixed traffic, New Zealand

- Physical queue jump lanes are designated for use by transit vehicles and only allow transit vehicles to pass a queue of general traffic ("jumping the queue") at a traffic bottleneck. When queue jump lanes are not integrated with traffic signals, they typically require a merging lane or bus bypass lanes on the far side of the bottleneck to allow the transit vehicle to safely merge into traffic.
- Queue jumpers integrated with traffic signals have a special traffic signal that gives an early green light to buses, allowing them to move into the general lanes ahead of other traffic. A right-turn-only signal is often displayed in advance of the bus-only green to clear any right-turning vehicles from the lane.

COST: $0.10 - $0.29 million per queue jump lane section per intersection (excluding ROW acquisition). Costs can be much less if existing roadway space can be rededicated for the purposes of queue jump lanes, such as an existing right-turn lane.

- Since most of the delay on urban streets is at intersections and other bottlenecks, queue jumpers can provide significant improvements in travel time without taking away travel lanes from other vehicles or widening the roadway.
- Can be used to facilitate bus movements from a right-side stop to a left-turn lane in a short distance.
- Can be used at non-intersection locations such as in advance of a narrower section of roadway, for example, a bridge or a narrow urban street.

- Requires coordination with the traffic signal system in order to ensure optimum functionality.

On-Street Bus Lanes

Reserving lanes for the exclusive use of transit vehicles can reduce running time and improve reliability. Other vehicles are restricted from using the lane by means of police enforcement. The status of the lane is indicated by signs, pavement markings, and sometimes a physical barrier. In some cases, non-transit vehicles are allowed to share the designated lane such as turning vehicles, taxis, high-occupancy vehicles, or bicycles. Bus lanes can operate at all times or only at certain times of the day, such as peak periods. There are several types of on-street bus lanes:

Curbside bus lane in San Pablo—AC Transit

- Curbside—Exclusive lane is adjacent to the curb. In this case, delivery vehicles are typically permitted, at least during off-peak hours. Lanes shared with right-turning traffic are, typically, not very effective unless treated as queue jump lanes, as previously described.
- Outside of parking lane—The bus lane is to the left of a permanent parking lane. In this case, the curb flares into the parking lane at stations to become a "bus bulb."
- Center (or Median-Running)—The bus lane is in the center of the roadway. In this case, it is necessary to create a loading platform between the bus lane and the general purpose lanes at stations. Alternatively, if the vehicle has left-side doors, a central platform shared by both directions of movement can be used. Commonly, medium anterial busways are physically separated from adjacent travel lanes.
- Contraflow—The bus lane runs opposite the direction of general traffic. This design is like a two-way street that operates in one direction only for general traffic. Contraflow lanes on the left side of the road require fencing because they operate contrary to the expectation of pedestrians.

REASONS TO IMPLEMENT

- Can permit buses to bypass traffic congestion, thus increasing the average and reducing variability of bus running speed.
- Increases the visual presence of transit in a corridor.

CONSIDERATIONS/ REQUIREMENTS

- Requires special analysis to determine whether lanes function all day or only during peak hours.
- Requires enforcement from use by other vehicles to retain the benefits of faster travel time and reliability.
- Public understanding of the use restrictions can be more difficult when they apply only in certain hours.
- Parking in curbside bus lanes is a notable problem where there are buildings with no rear access; some allowance must be made for deliveries.
- Requires strategy to maintain political support.
- Contraflow bus lanes may require special pedestrian safety programs or physical design treatments to address special pedestrian safety conditions.
- Implementation of bus-only streets requires a plan to accommodate local access to delivery vehicles for owners and users on the affected street.

Bus-Only Streets

Entire roadways can be restricted to buses only. Bus-only streets are typically applied in central business districts as "bus malls" where many different bus services in addition to BRT services converge. Generally, access to delivery vehicles is permitted at least at some times.

Bus only street in pedestrian transit mall—Denver, Colorado

- In central business districts, it may be desirable to concentrate bus routes on a single street and divert all other vehicles (except local deliveries) to a parallel street. This solution can reduce delays due to congestion while maximizing bus use of restricted lanes.
- Bus-only streets make it easier for customers to find downtown bus stops and to transfer between routes.

Off-Street Running Way Types

Expressway Bus Lanes

Buses can operate in expressways in High Occupancy Vehicle (HOV), High Occupancy-Toll (HOT), or bus-only lanes. These can be shoulder lanes, median lanes, or contraflow lanes. Where there are peak directional flows, contraflow lanes can be created either through manually placing barriers or by the use of a "zipper" truck that can move a concrete lane barrier. Alternatively, operation of bus-only lanes, or HOV lanes with buses, can be reversible and limited to peak direction use only.

Bus and taxi lane on British motorway

COST: $2.5 - $2.9 million per lane mile (excluding ROW acquisition)

REASONS TO IMPLEMENT

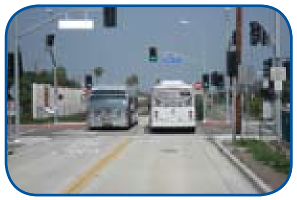
- Can guarantee free-flow travel speeds at all times mitigating the impacts of recurring or intermittent congestion.

CONSIDERATIONS/ REQUIREMENTS

- Like on-street bus lanes, requires active enforcement to limit delays and congestion caused by other vehicles.

At-Grade Transitways

Roads for the exclusive use of transit vehicles can be created where there is available right-of-way, such as a railroad corridor that is no longer in use and where there is sufficient transit demand to warrant the investment that will support frequent bus service. Where there is sufficient cross-section, transitways can also operate adjacent to active rail corridors. In some cases, right-of-way for exclusive lanes may be wide enough to accommodate only one single bi-directional lane. In such situations, transit service is limited to the peak direction only or service in both directions if frequencies are low and the single-lane section is short.



Orange Line, Los Angeles

COST: (not including ROW): $6.5 - 10.2 million per lane mile

REASONS TO IMPLEMENT

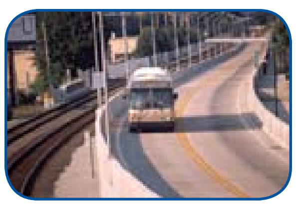
- At-grade transitways reduce congestion-related delays between intersections and promote reliability of service.

CONSIDERATIONS/ REQUIREMENTS

- Requires attention to safety at grade crossings with cross streets including education programs, new traffic control measures, safety devices, and even the possible installation of crossing gates.

Grade-Separated Transitways

Grade-separated transitways traverse cross streets with overpasses or underpasses, allowing transit vehicles to operate unimpeded at maximum safe speeds between stations. They are separated from congestion along local streets at intersections and adjacent highways. Underpasses or overpasses can be used at intersections, with the bulk of the right-of-way at grade, to reduce costs.



East Busway, Pittsburgh

COST: (not including ROW):

Aerial transitway:	$12 - $30 million per lane mile
Below-grade transitway:	$60 - $105 million per lane mile
Additional lanes: $6.5:	$10 million per additional lane mile

REASONS TO IMPLEMENT

- Can offer expressway-like speeds and a high degree of reliability, with few or no conflicts from other vehicles.

CONSIDERATIONS/ REQUIREMENTS

- Where the volume of buses is high and where there is a mix of standard and express services, multiple lanes may be necessary to add capacity and to allow passing, particularly at stations.

Running Way Markings

Running way markings are effective devices for communicating to passengers and motorists that BRT running ways are present. This is important for multiple purposes: to facilitate faster travel times, and to promote safety. Secondarily, they may provide visibility for the system. Especially where running ways are for the exclusive or semi-exclusive use of transit vehicles, the special status of the lanes, or entire roadway, can be designated through signs, lane markings, barriers, and special pavement, as described below. The design, use, and placement of these devices are governed by the *Manual on Uniform Traffic Control Devices* (MUTCD), which is supported by the U.S. DOT Federal Highway Administration (*http://mutcd.fhwa.dot.gov/*).

Running Way Markings

Signs and Pavement Markings

Signs and pavements markings are required regulatory devices to restrict use of the road or lane to designated vehicles. They represent a very basic running way treatment. The MUTCD also provides standards for the type of lane markings and symbols that may be used, depending on the type of vehicles allowed, the location of the lane, and the nature of the restriction. (In the 2003 edition of the MUTCD, signs for bus lanes are discussed in Section 2B.26, Preferential Only Lane Signs and pavement markings for bus lanes are discussed in Section 3B.22, Preferential Lane Word and Symbol Markings. The standard allows for designating lanes for any combination of specific vehicles [e.g., bus, taxi, two-person carpool, bicycle]. The diamond symbol on signs and pavement markings is used only to indicate HOV lanes, that is, those that are open to cars with some minimum occupancy [e.g., 2, 3, or 4 persons]. These lanes are normally open to buses also. However, lanes for buses that do not permit carpools use text-only signs such as R3-11B. The signs can be used for lanes that are in use only in certain time periods and can be used on either expressways or conventional roads.)

Example of a ground-mounted bus lane sign, MUTCD R3-11B.

Pavement markings—Boston Silver Line

REASONS TO IMPLEMENT

- Used as a minimum requirement. Regulatory traffic signs are required to make lane restrictions legally enforceable.
- Pavement markings can greatly increase the visibility of lane restrictions.

CONSIDERATIONS/ REQUIREMENTS

- To increase visibility and compliance, overhead lane signs should be considered in addition to or instead of ground-mounted signs.
- Pavement markings require ongoing maintenance.

Raised Lane Delineators

Raised curbs, bollards, medians, or raised lane delineators can highlight the distinction between general purpose lanes and BRT running way lanes. The MUTCD permits such measures; preferential lanes "might be physically separated from the other travel lanes by a barrier, median, or painted neutral area." Raised lane delineators create a physical divider that motorists can see or feel. As such, they create restrictions on use by certain classes of roadway users.

LYNX Lymmo

REASONS TO IMPLEMENT

- Deters motorists from entering a reserved lane.
- Are particularly useful in locations where no turns across the reserved lane are permitted and where there is enough cross-section to provide a substantial, visible divider, such as a raised median.

CONSIDERATIONS/ REQUIREMENTS

- Some larger types of dividers could create extra safety considerations for certain classes of roadway users, especially motorcyclists or bicyclists.
- As with pavement markings, dividers require ongoing maintenance.
- Since dividers prevent traffic from entering the lane to make a turn or access on-street parking, such dividers may be more appropriate for permanently exclusive lanes.

Pavement Color and Material

Designated BRT running ways can be identified through the use of a different pavement color and/or the use of a different pavement material, such as colored asphalt or concrete.

Key routes, Nagoya, Japan

REASONS TO IMPLEMENT

- Visibly reduces the number of motorists who enter a restricted lane inadvertently.
- Increases the visibility and image of transit services.

CONSIDERATIONS/ REQUIREMENTS

- Use of alternative pavement color and material may require exceptions to existing traffic control practice, especially where jurisdictions adhere to the MUTCD. The MUTCD currently does not permit colored lanes, except through its experimentation procedure. The manual also requires that colored pavement be used only to reinforce a traffic control that is legally in force at all times. However, contrasting pavement materials that have no explicit regulatory meaning, such as a concrete bus lane adjacent to an asphalt general-purpose lane, can be used.
- As with pavement markings, lanes with alternate pavement color require ongoing maintenance and cleaning to maintain a consistent and clean look.

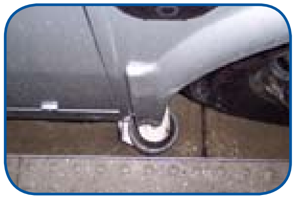
Running Way Guidance

Running way guidance can be used along the line-haul portion of a route to permit higher speed travel in narrow corridors. Some guidance technologies also can be used to permit safe operation on narrow streets with frequent pedestrian use, at reduced speeds. A third application of guidance technology consists of short sections of concrete guideway used on streets to create narrow bus lanes and to prevent unauthorized vehicle use, often at intersection approaches. Guidance technologies can also be used for precision docking (see section on Horizontal Gap in the Stations).

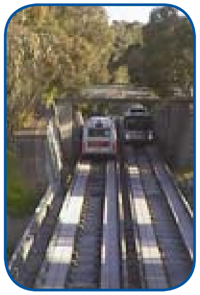
Running Way Guidance

Curb Guidance

Vehicles can be equipped with horizontal rubber guidewheel tires that follow vertical curbs. The guidewheels are attached to arms connected to the bus steering mechanism. Buses can drive normally off the guideway. Most systems use guidance in multiple short segments to provide dedicated lanes in congested areas. Hundreds of buses are now used daily on more than a dozen systems in cities around the world, and, as of 2007, two additional systems were under construction in the UK.



Cleveland BRT bus with guidewheels for precision docking



Adelaide system showing high speed operation on narrow row

REASONS TO IMPLEMENT

- Provides smooth operation at high speeds. Some routes with dedicated rights-of-way operate at 100 kph (62 mph). Operation is robust in severe operating conditions such as heavy precipitation. High-speed operation is possible in narrower rights-of-way, which can result in substantial cost savings where right-of-way is constrained or where bridges or underpasses may otherwise require wider sections.
- Guided bus transitways are self-policing, since vehicles not equipped with guidewheels cannot operate on the guideway.
- Provides guaranteed level boarding.

CONSIDERATIONS/ REQUIREMENTS

- Curb-guided bus technology is non-proprietary; any bus manufacturer can equip buses with guidewheels (which are not expensive), and any agency can construct guideways at a cost similar to construction of conventional busways. Some specialty knowledge is required.

Single Rail Guidance

There are two suppliers of systems based on a steel wheel on the vehicle following a single center rail. Several small systems have been installed (in France, Italy, and China). Vehicles are very specialized. Operation is limited to 30 kph (about 19 mph) and thus is more suited to urban rather than express operation. Operating capability off guiderail is very limited.

The technology is more like rail than bus in that it can only operate on the guideway, thus eliminating many of the advantages that bus systems enjoy.

TVR in Nancy, France

- Compared to conventional bus systems, narrower rights-of-way can be used and precision docking with level boarding will be achieved.
- Use of single rail guidance with rubber-tired vehicles may simulate light rail.

- Procurement of systems is proprietary.

Optical Guidance

Optical guidance systems use video sensors on vehicles that read lines painted on the pavement to delineate the path of the vehicle. The only infrastructure change needed to the running way is the application of pavement markings. Buses can operate with normal manual steering without the guidance system engaged. Operation is limited to 30 kph (about 19 mph). The technology is useful for urban operation in narrow streets and pedestrian areas and for precision docking but is not suitable for high-speed line haul operation due to the possibility of guidance failure at high speeds. The only city with revenue operation is Rouen, France, but the technology was tested in Las Vegas and is under construction for Cambridge, UK.

Rouen, France

COST: $100,000 per vehicle.

- Optical guidance requires little investment in right-of-way. Its main uses are precision docking and low-speed operation on narrow rights-of-way.

- Because complex electronic detection and mechanical control systems are required, optical guidance adds a significant amount to the vehicle cost.
- These markings must be maintained to a sufficient level of contrast for the sensors to reliably detect them. Maintaining the pavement markings may also add ongoing maintenance costs.

Effects of Running Way Elements on System Performance and System Benefits

Exhibit 2-1 summarizes the links between the running way elements and the BRT system performance indicators and system benefits identified in Chapter 1. These links are explored further in Chapters 3 and 4.

Exhibit 2-1A: Summary of Effects of Running Way Elements on System Performance

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Running Way Location • On-Street • Off-Street	Off-street running ways normally reduce running time more than on-street but may increase access time.	Off-street running ways should provide greater reliability except on congested freeways.	Exclusive busways can become part of the image of a BRT and the subject of a marketing a campaign. An off-street transitway can be used as the primary branding element of a BRT. An on-street running way can be part of an overall street-scape renovation or upgrade.	Segregation from other traffic and pedestrians may decrease BRT vehicle collisions compared to on-street operations.	Off-street running ways may have higher capacity due increased number and frequency of transit vehicles that the bus lanes can accommodate. Off-street running ways may allow multiple lanes, which accommodates more vehicles and express or limited stop service as well as all-stop service.	On-street running ways, are generally closer to land uses, require less walking and access time, and have fewer physical barriers.
Level of Transit Priority On-Street • Mixed-Flow with Queue Jumper • On-Street Bus Lane	Priority measures, if effectively implemented and enforced, should reduce running time, particularly in congested situations.	Priority measures should improve reliability.	Clear, enforced priority for running ways operating on regular streets improves the visibility and image of transit.	Separation of BRT vehicles from other traffic can reduce collisions.	Priority measures that reduce congestion delay also increase throughout.	
Off-Street • At-Grade Transitway • Grade Separated Transitway	Off-street running ways with at-grade intersections may offer lower travel time benefits than fully grade-separated running ways.	Both at-grade and grade-separated running ways demonstrate good travel time reliability.	Both grade-separated and at-grade transitways can be used as the system's central branding element.	Potential conflict points such as cross-street intersections and other at-grade vehicle and pedestrian crossings must be addressed.	Busways that bypass street-level intersections can accommodate higher vehicle numbers and frequency.	

Exhibit 2-1A: Summary of Effects of Running Way Elements on System Performance (cont'd.)

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Running Way Marking • Signage & Pavement Markings • Raised Lane Delineators • Pavement Color and Material	Clear designation of exclusive running ways can reduce unauthorized use.	Clear designation of exclusive running ways can reduce unauthor-ized use.	Markings highlight that BRT running ways are a special reserved treatment. Attractive markings or pavement coloring can enhance the system's visual image.	Clear designation of exclusive running ways can reduce entry of non-BRT vehicles and pedestrians.	Clear designation of exclusive running ways may reduce unauthorized use and thus increase throughout.	
Running Way Guidance Type • Curb Guidance • Single Rail Guidance • Optical Guidance	Curb guidance reduces running time, especially in narrow rights-of-way. May allow bus lanes or transitways to fit where otherwise infeasible.	Precision docking allows level boarding and thus reduces boarding and alighting delay.	Guidance provides a smoother ride, enhancing image.	Curb guidance permits safer operation at higher speeds in narrow corridors.	Guidance may increase throughput through reduced running time and boarding delay.	Guidance systems can reduce the horizontal gap between vehicles and stations, facilitating boarding for all passengers, but especially for passengers who use wheelchairs or other mobility aids.

Exhibit 2-1B: Summary of Effects of Running Way Elements on System Benefits

	System Performance				
	Higher Ridership	Capital Cost-Effectiveness	Operating Cost-Efficiency	Transit-Supportive Land Development	Environmental Quality
Running Way Location • On-Street • Off-Street	Off-street running ways can speed service and thus attract riders, but they may not be well located.	Newly-created off-street running ways are expensive and thus need high ridership to justify their cost.	Higher travel speeds greatly reduce hourly operating costs. However, off-street rights-of-way will increase maintenance costs compared to shared infrastructure.	Off-street running ways generally offer more opportunities for development of new areas. On-street running ways may better promote redevelopment of existing urban areas. On-street project that include streetscape and/or utility renovations can attract developers.	New off-street running ways such as busways will require considerable construction and environmental permitting. Off-street running ways may be able to isolate noise away from populated areas.
Level of Transit Priority On-Street • Queue Jumper • Arterial Bus Lane	Priority measures can increase ridership to the extent that they increase service quality.	Costs vary enormously, depending on type of priority treatment. In general, greater levels of transit priority correlate with higher costs.	The major cost is additional enforce-ment.	More substantial running way invest-ments may attract developers by indicating permanence and a high-quality image.	Affects primarily through-service quality. Separated running ways may permit more landscaping and bike and pedestrian paths.
Off-Street • At-Grade Transitway • Grade Separated Transitway	Grade-separated transitways may attract more riders by ensuring higher speeds and safety from accidents with unauthorized vehicles.		Faster speed and more riders.	More permanent running way investments tend to attract more development.	Grade-separated transitways will allow higher average speeds with reduced stopping, which lowers emissions.
Running Way Marking • Signage & Pavement Markings • Raised Lane Delineators • Pavement Color & Material	Running way markings help ensure compliance with priority restrictions, thus reducing delays and the potential for accidents, which may damage rider perception of service.	Costs vary enormously, depending on type of priority treatment. In general, greater levels of transit priority correlate with higher costs.	The major cost is additional enforce-ment.	Affects only through-service quality.	Affects only through-service quality. Certain distinctive pavement markings and colors can also create a more attractive visual impact.
Running Way Guidance Type • Curb Guidance • Single Rail Guidance • Optical Guidance	Guidance can help improve travel times, which may bring higher ridership.	Costs vary enormously, depending on type of priority treatment. In general, greater levels of transit priority correlate with higher costs.	The major cost is additional enforce-ment.	Affects only through-service quality	Curb guidance can minimize need for widening rights-of-way. Other effects through-service quality.

Planning and Implementation Issues

Implementation Issues During Planning and Project Development

Availability of Right-of-Way

The first decision in planning a BRT project is how running ways should be configured to serve the corridor and the activity centers within it. Existing expressways or HOV lanes could be used or improved, or new transitways could be created, depending on the availability of suitable right-of-way. In most metropolitan areas, only a very limited number of possible locations for new transitways exist. Disused railway alignments are the most common locations and can provide higher speeds, with the potential to link the right-of-way with adjacent land uses and activity centers. Expressways with HOV lanes and grade-separated transitways will generally provide much higher speeds. However, using such rights-of-way may increase route distance or walking time if they are not located near most origins and destinations. Without right-of-way for off-street running ways, existing roadways would need to be incorporated into the BRT network.

Public/Political Acceptance of Priority Measures

Priority measures such as bus lanes on arterials or expressways require dedicating some space to transit and restricting general traffic. Where candidate bus lanes are already open to all traffic, it is often politically difficult to change their use. Creating bus lanes by adding to the roadway or expressway is more politically acceptable but can be expensive if the corridor does not have additional width (such as a median) that can be easily converted. The use of curb-guided buses can minimize the width requirements and also eliminate the problem of unauthorized use. Queue jumpers and transit signal priority are less visible and may be more readily accepted, unless they lead to a significant degradation in intersection performance.

Even when heavily used (e.g., one bus every two minutes), bus lanes can look empty compared to adjacent congested lanes. This appearance makes it politically difficult to create, maintain, and enforce exclusive bus lanes in congested areas, which are precisely the places they are most needed. Permitting certain other authorized vehicles to use the lanes, such as minibuses, taxis, motorcycles, and bicycles, may reduce this image problem without eliminating the benefits. Short stretches of bus lanes, particularly contraflow lanes, may provide a substantial share of the benefits without the appearance of wasting urban road space.

Implementation Issues During Operation

Enforcement

Maintaining exclusive bus lanes usually require police enforcement. Less enforcement may be needed when such lanes are visually distinct from general lanes and when violations are more noticeable. Enforcement generally requires the cooperation of a police force, often not under the control of the transit agency. Fines need to be high enough to deter violations with a sustainable amount of enforcement activity. Physical barriers and other design measures to improve compliance must conform with standards such as the MUTCD and state highway design manuals. Enforcement strategies frequently must also accommodate the operation of vehicles from other transit agencies and from emergency services such as police, ambulance, and fire services. Busways, including those on-street that are designed for curb-guided buses, are too narrow to be used by unauthorized traffic and therefore eliminate the need for policing.

Intersection Conflicts

Transitways with at-grade intersections may increase the risk for collisions, generally from cross traffic failing to obey traffic signals. One source of this problem comes from motorists traveling on the cross street who fail to recognize that an intersection is ahead, possibly because a busway intersection may be smaller or less noticeable than many signalized urban intersections. The other source comes from motorists traveling on a street parallel to the busway who turn into the cross street and do not expect another cross street (the transitway) close to the major street. Use of crossing gates, as used on some light rail systems, may be considered, although such a solution may not conform to current practice. Other safety devices such as separate traffic signal displays may also be considered. Separate traffic signal displays, with proper phasing can be helpful.

Experience with BRT Running Ways

Exhibit 2-2A and 2-2B present an overview of worldwide BRT systems with on-street running ways and off-street running ways, respectively.

Among the cities included here, those in the U.S. are significantly more likely to employ an on-street running way with limited priority treatments. However, since the publication of the previous edition of "Characteristics of BRT," several U.S. projects with significant segments of on-street or off-street dedicated running ways have opened (in part or in full), including the Los Angeles Orange Line, Cleveland HealthLine, the Boston Silver Line Waterfront service, and the EmX in

Eugene, Oregon. Of the 13 U.S. systems that operate exclusively on-street, most have very little or dedicated running way components, and few use queue jumpers. Las Vegas and Cleveland are the only systems to incorporate a running way lateral guidance technology; Las Vegas' optical guidance system however, is no longer activated.

In contrast, almost all of systems in the rest of the world have some off-street component. The European systems typically combine on- and off-street running ways, and, as such, operate primarily at-grade. BRT systems in Latin America, Australia, New Zealand, and China are more likely to operate off-street for all or most of their routes, with both at-grade and grade-separated operation. Lateral guidance is most commonly used in Europe; of the other global systems, only Adelaide also uses a guidance technology. Finally, while BRT outside the U.S. is more likely to allow vehicle passing, it is still a minority of systems overall that have this capability.

Exhibit 2-2A: Experience with BRT Running Ways—On-Street-Only Projects

	Albuquerque	Boston	Chicago	Cleveland	Eugene	Honolulu	Kansas City	Las Vegas
	Rapid Ride – Red Line	Silver Line Washington St	Express	Healthline	EmX Green Line (Franklin Corridor)	City Express	MAX	North Las Vegas MAX
Running Way Description	On-street	On-street	On-street	On-street	On-street	On-street	On-street	On-street
Number of Routes	1	1	3 (reported data)	1	1	2	1	1
Total System Route Miles	13.8	2.4	36.7	7.1	4	27	6	7.5
• Mixed Flow Lanes	13.1	0.2	36.7	2.7	1.4	27	6	3
• Exclusive Bus Lanes	0.7	2.2		4.4	2.5		Along some segments at certain times of day	4.5
Queue Jumpers	No	No	No	No	Yes	No	No	One location
Running Way Marking Type	Signage	Signage, striping	None	Signage, Rumble Strips	Raised delineators, pavement coloring, markings	None	Pavement markings, signage	Signage, striping
Lateral Guidance Type	None	None	None	Mechanical	Plastic Striping	None	None	Optical, no longer in use

Exhibit 2-2A: Experience with BRT Running Ways—On-Street-Only Projects (cont'd.)

	Los Angeles	Oakland	Sacramento	San Jose	Santa Monica	York Region, Ontario	Hangzhou
	Metro Rapid	San Pablo Avenue Rapid	Ebus	Rapid 522	Lincoln Rapid	VIVA	Line B1
Running Way Description	On-street	On-street	On-street	On-street	On-street	On-street	On-street
Number of Routes	19	1	1	1	1	5	1
Total System Route Miles	229 (as of 2007)	14	12	25	10.7	50	6.2
• Mixed Flow Lanes	229 (as of 2007)	14	8	25	10.7	50	6.2
• Exclusive Bus Lanes			4			Some bus-only intersection lanes	
Queue Jumpers	Yes	No	One location	Two locations	No	No	No
Running Way Marking Type	None	None	None	None	Signage	None	Striping
Lateral Guidance Type	None	None	None	None	None	None	None

Exhibit 2-2B: Experience with BRT Running Ways—Projects With Off-Street Components

	Boston	Honolulu	Los Angeles	Miami	Orlando	Phoenix
	Silver Line Waterfront	County Express	Orange Line	South Dade Busway	LYMMO	RAPID
Running Way Description	On- and off-street	On- and	On- and off-street	Off-street only	Off-street only	On- and off-street
Number of Routes	3	off-street	1	1	1	4
Total System Route Miles	8.99.3	1	14.5	8	3	75.3
• On-Street Mixed Flow Lanes	6.3	39	1			31.5
• On-Street Exclusive Bus Lanes		18				31.5
• Off-Street Mixed Flow						43.8
• Off-Street Reserved Bus Lanes		3.5 miles				
• At-Grade Transitway		17.5 miles	13.5	8	3	
• Grade-Separated Transitway	1.0 mile in tunnel used by 3 routes					
Type of Grade Crossing Treatments			Traffic signals, signage	Traffic signals	Traffic signals	None
Passing Capability	None	Using adjacent mixed-flow lanes	Passing lane at each in-line station	Bus pull-outs	None	Bus pull-outs
Running Way Marking Type	Signage	Zipper lane concrete barrier	Separate ROW, signage, pavement	Separate ROW	Busway barrier, gray pavers	Signage
Lateral Guidance Type	None	None	None	None	None	None

Exhibit 2-2B: Experience with BRT Running Ways—Projects With Off-Street Components (cont'd.)

	Pittsburgh			Halifax	Ottawa	Bogotá	Guayaquil	Pereira
	East Busway	South Busway	West Busway	Metrolink	Transitway	Transmilenio	Metrovia	Megabus
Running Way Description	Off-street only	Off-street only	Off-street only	On- and off-street	On- and off-street	Off-street only	Off-street only	Off-street only
Number of Routes				Multiple	Multiple	Multiple		Multiple
Total System Route Miles	9.1	4.3	5	23.2	30.8	52	10	17 miles
• On-Street Mixed Flow Lanes				12.1	2.1			
• On-Street Exclusive Bus Lanes				0.5	8.7			
• Off-Street Mixed Flow	0.4		0.4	10.6				
• Off-Street Reserved Bus Lanes					1.2			
• At-Grade Transitway						52	10	17 miles
• Grade-Separated Transitway	8.7	4.3	4.6		18.8			
Type of Grade Crossing Treatments			Signal priority (magnetic loop sensors)	None				
Passing Capability	Passing allowed	Passing allowed	Passing allowed	None	Bus pull-outs	Bus pull-outs at many stations, some with two lanes	No passing	No Passing
Running Way Marking Type	Separate ROW	Separate ROW	Separate ROW	Signage	Signage, pavement color	Signage	Signage	Signage
Lateral Guidance Type	None	None	None	None	None	None	None	None

Exhibit 2-2B: Experience with BRT Running Ways—Projects With Off-Street Components (cont'd.)

	Utrecht	Adelaide	Brisbane	Sydney	Auckland	Beijing	Kunming
	Busway	Northeast Busway	Southeast Busway Inner Northern Busway	T-Ways	Northern Busway	Line 1 BRT	Busway Network
Running Way Description	On- and off-street	Off-street only	Off-street only	Off-street only	Off-street only	Off-street only	Off-street only
Number of Routes	3		2	3		1	Multiple
Total System Route Miles	10.3	7.46	12	34.3	3.7	10.3	24.9
• On-Street Mixed Flow Lanes	3.5						
• On-Street Exclusive Bus Lanes	2.0			8.2			
• Off-Street Mixed Flow						2.2	
• Off-Street Reserved Bus Lanes							24.9
• At-Grade Transitway	4.8		8	26.1		8.1	
• Grade-Separated Transitway		7.46	12		3.7		
Type of Grade Crossing Treatments	At-grade, underpass through roundabout, overpass canal			Mix of at-grade signals and grade separations	N/A	Mix of at-grade signals, overpasses and underpasses	Signals
Passing Capability	None	Passing at interchanges due to single track	Bus pull-outs at stations	Bus pull-outs at stations	Bus pull-outs at stations	Multiple lanes	None
Running Way Marking Type	Signage, pavement markings and color	Signage	Signage	Signage Red Pavement	Signage		Striping
Lateral Guidance Type	None	Mechanical guide Rollers on front axle	None	None	None	None	None

STATIONS

Description

Role of Stations in BRT

Stations form the critical link between the BRT system, its customers, and other public transit services offered in the region. They also clearly represent the identity of a BRT system through both visual features and physical amenities. Stations, therefore, can play a significant role in distinguishing a BRT system from other public transit services, portraying a premium-type service while integrating with and enhancing the local environment.

Because BRT generally serves high-demand corridors and has a limited number of stops, more customers per station can be expected compared to a typical local bus route. BRT stations must provide more comfort and amenities than standard bus stops, which in some communities have nothing more than a sign on a pole. As with rail stations, BRT stations should provide passenger comfort, passenger information, and a visible image of the system.

Characteristics of Stations

Stations have seven primary characteristics:

- ***Station Location***—Stations can be located on streets, adjacent to busways or expressways ("on-line"), or in transit centers, which serve more than one transit route and are typically off-street.
- ***Station Type***—The scale and scope of the station shelter architecture define the station type. There are varying categories of station types based on increasing size and complexity: simple shelter, enhanced shelter, station enclosure, station building, and intermodal transit center. The station type can convey the brand identity of the system and plays a role in distinguishing the BRT system from other public transit services.
- ***Passenger Amenities***—Like rail stations, BRT stations typically have features to provide information about the route and the system, enhance passenger comfort and convenience, and enhance the safety and security of the system. These features can also convey a brand identity and improve the image of transit, even for those who are not using the system.
- ***Curb Design***—Curb design affects the ability of all customers to board and alight, but particularly affects those who are mobility-impaired or who have strollers, bicycles, or luggage. Passengers traditionally board buses by stepping from a low curb up to the first step on the vehicle, then climbing additional steps. Given the widespread adoption of low-floor vehicles, boarding has become easier for all passengers. Platforms at the same height as vehicle floors can further enhance the customer experience and reduce dwell time. No-gap, no-step boarding and alighting can be created by increasing the platform height to meet the floor height and reducing the distance between stopped bus and curb. This approach is particularly effective when combined with proof of payment fare collection, allowing boarding at all doors.
- ***Platform Layout***—Platform length and the number of berthing spaces is a major element of station design. It affects how many vehicles can simultaneously serve a station and how passengers must position themselves along a platform to board a given service.
- ***Passing Capability***—The ability of vehicles to pass each other can increase speed and reduce delay. Passing capability is important when the operating plan calls for express and local routes. When BRT vehicles operate on ordinary streets, passing is generally accomplished using adjacent general traffic lanes. With off-street service such as an HOV lane or transitway, passing areas must be designed into the system, typically at stations.
- ***Station Access***—Passengers access stations on foot, by bicycle, from a private vehicle, or from another transit service. With off-street stations, particular consideration must be given to pedestrian and vehicle routes, as well as the provision of waiting and parking areas for motor vehicles and secure parking for bicycles. The provision of parking at BRT stations can reduce travel time for customers arriving by automobile or bicycle from outside the station area and can expand the reach of the system. If stations are located next to development such as shopping centers or office parks, parking areas can often serve both transit and adjacent land uses.

Station Options

Station Location

Stations can be located on streets, adjacent to busways or expressways ("on-line"), or in transit centers, which serve more than one transit route and are typically off-street.

Station Location

On Street, Curb Adjacent

In principle, stations can be located along any curb on a route served by BRT. The three possible types of on-street stops are near-side (with respect to the intersection), far-side, and mid-block. All things being equal, far-side stops are generally more favorable, since the bus can leave the stop as soon as boarding is complete without waiting for the signal. Far-side stops also facilitate the use of transit signal priority. However, there are advantages of near-side stops, such as reducing the number of stops at a single intersection. Physical conditions, such as the location of driveways, storefronts, and trees, play a role in determining station location.

Basic Stop Melnea Station—Silver Line

REASONS TO IMPLEMENT

- Bus stops along a street can be located to serve any use on that street, minimizing walking time. Locating stations adjacent to the curb works with operation at the curb lane and in situations where buses have a combination of exclusive lanes and mixed flow lanes.

CONSIDERATIONS/ REQUIREMENTS

- There is a temptation with the ease of curb-adjacent stations to place stops anywhere someone might want to get off, rather than increasing efficiency and service quality by keeping the distance between stops at least 1/4 mile (typically 1/2 mile or more) for BRT service.
- Building entrances set back from the street (as at shopping centers and office parks) increase walking distance.
- Difficult to accommodate drop-off areas or park-and-ride with on-street spots.
- The transit agency generally does not control either the right-of-way or the wayside. Cooperation from other entities is necessary in designing, building, maintaining, and policing the roadway and the station area in a way favorable to transit service.

On-Street, Island Platform

The other configuration for on-street BRT operations is to serve an island platform, either with just one lane separated from the curb or in a center median. Such platforms serve BRT running ways that are not adjacent to the curb.

On-Street Island Platform in Curitiba—RIT

REASONS TO IMPLEMENT

- Serves BRT running ways that are not adjacent to the curb (either with flow or contraflow).
- Separates station infrastructure more clearly from sidewalk pedestrian infrastructure.

CONSIDERATIONS/ REQUIREMENTS

- Development of pedestrian paths to the station requires consideration of:
  - protection from vehicular traffic
  - adequacy of access/egress for normal and peak loads and emergency conditions
  - compliance with accessibility guidelines
- Median stations may require vehicles with left-side doors.
- Station infrastructure should include safety features to protect from errant motorists

Off-Street, On-Line Station Adjacent to Land Uses

When transitways are developed within their own freestanding rights-of-way or adjacent to parallel highways (rather than within them), they are served with on-line stations adjacent to land uses. At these stations, BRT vehicles stay on the running way when serving the station. Passengers have the option of walking directly from the station platform to nearby neighborhoods or activity centers or connecting transit service.

Ottawa Transitway

REASONS TO IMPLEMENT

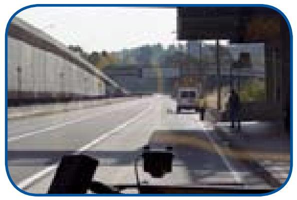
- Serves off-street BRT running ways without unnecessary deviations with the most direct pedestrian connections to adjacent land uses.

CONSIDERATIONS/ REQUIREMENTS

- Attention to effective urban design linkages can enhance integration with surrounding urban districts or neighborhoods.
- Stations adjacent to highways can act as buffers between highways and neighborhoods.

Off-Street, On-Line Station within Highway Right-of-Way

On-line stations within highway right-of-way are similar to other on-line transitway stations but are separated from adjacent land uses by the physical infrastructure of a highway. Typically, they serve facilities such as HOV lanes. Greater allowance must be made for entrance ramps and merging areas due to the higher volume of expressway traffic. On-line stations can also be grade separated from the expressway. In this case, pedestrian bridges or underpasses are required for access to the station.



El Monte Busway

- On-line stations reduce the amount of vehicle time spent away from the express facility. There is generally ample room to provide multiple bus berths, passenger amenities, and even car parking areas.
- Stations can be designed to provide direct walking access to adjacent land uses.

- On-line stations are often further away from passenger destinations, given the location of potential transitways and existing expressways.
- Off-street stations are generally much more expensive to build and maintain than on-street stations.
- For stations built near expressways, traffic noise is a concern.

Off-Street, Off-Line Station

Off-line transitway stations place the station and passenger access on the side of highway infrastructure close to land uses. As they are located off the main running way, serving these stations requires diverting BRT vehicles from the main route. Often, off-line stations are transit centers that accommodate multiple routes. They may permit transfers from BRT service to local bus and other public transit modes, e.g., rail transit, or intercity bus and rail. Transit centers often have park-and-ride lots, drop-off areas, bicycle parking, and taxi stands.

COST: $2 - $20 million per facility or higher (includes the cost of platforms, canopies, large station structure, passenger amenities, pedestrian access, auto access and facilities for all transit modes served; does not include soft costs).

Ottawa Transitway Intermodal Station

- Places passenger access closer to adjacent land uses without requiring walking across a highway.
- Can serve as a downtown or regional hub for the entire system.
- Provides space for access to multiple services, including BRT trunk or express service.
- Transit centers, with their concentration of transit services providing many choices, have the greatest ability to influence land use decisions.

- Transit centers may be the most effective when they combine the transfer and access functions with an important customer destination. Central Business Districts and regional shopping centers thus make good candidates for transit centers.
- Generally requires a branching route structure for the main transitway facility.

Basic Station Types

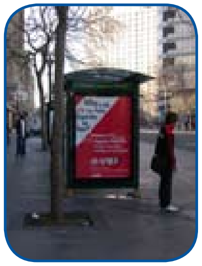
Station types are defined by the scale and scope of the infrastructure associated with the station shelter. In increasing order of scale, there are five basic BRT station types:

Basic Station Types

Simple Shelter

A simple shelter is the simplest form of the five BRT station types. It consists of a "basic" transit stop with a simple shelter (often purchased "off the shelf") to protect waiting passengers from the weather. In general, this type of station has the lowest capital cost and provides the lowest level of passenger amenities.

COST: $15,000 - $20,000 per shelter (includes cost of shelter only; does not include cost of platform or soft costs).



San Pablo Rapid Bus Shelter

Enhanced Shelter

Enhanced BRT stations include enhanced shelters, which are often specially-designed for BRT to differentiate it from other transit stations and to provide additional features such as more weather protection and lighting. This BRT station type often incorporates additional design treatments such as walls made of glass or other transparent material, high-quality material finishes, and passenger amenities such as benches, trash cans, or pay phones. Enhanced shelters are often installed for on-street BRT applications to integrate with the sidewalk infrastructure.

COST: $25,000 - $35,000 per shelter (includes cost of the shelter only; does not include cost of platform or soft costs).

Enhanced stop along East Busway in Pittsburgh

Station Enclosure

Often based on a custom design, station enclosures are designed specifically for a BRT system and are fabricated off site, allowing for identical and modular designs for multiple locations. The station enclosure may include level passenger boarding and alighting, a full range of passenger amenities including retail service, and a complete array of passenger information.

COST: $150,000 - $300,000 per station (lower-cost stations include cost of canopy, platform, station enclosure, and pedestrian access).

Curitiba tube station

Station Building

The designated BRT building represents a large enclosure for passengers. Designs for station buildings are specific to each station location and often include enclosures for passengers waiting for both directions of travel, pedestrian passageways, accessibility features such as ramps and elevators, and grade-separated connections from one platform to another, as well as a full range of passenger amenities including retail service and a complete array of passenger information.

COST: $500,000 - $2.5 million per station (lower-cost stations include cost of canopy, platform, station enclosure, and pedestrian access; higher-cost stations are designed for higher ridership and include longer platforms and canopies, larger station structure, passenger amenities and roadway access; parking facility and soft costs are not included.

Transit Center in Brisbane, Austrailia

Intermodal Terminal or Transit Center

The intermodal terminal or transit center is the most complex and costly of the BRT stations listed in this section. This type of BRT facility often will have level boarding and a host of amenities and will accommodate the transfers from BRT service to local bus and other public transit modes such as local rail transit, intercity bus, and intercity rail.

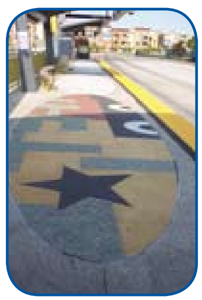
COST: $5 million - $20 million per facility or higher (includes the cost of platforms, canopies, large station structure, passenger amenities, pedestrian access, auto access, and transit mode for all transit modes served; does not include soft costs).

Intermodal Station along Miami-Dade Busway

Passenger Amenities

Passenger amenities can make the experience of approaching and waiting in stations attractive, comfortable, and convenient. There are a multitude of individual components that comprise passenger amenities. These can be classified into three general categories: passenger information amenities, passenger comfort and convenience amenities, and passenger security amenities. Often, these amenities are implemented as different suites of elements to create a complete experience for passengers.

Passenger Amenities

Passenger Amenities		REASONS TO IMPLEMENT	CONSIDERATIONS/ REQUIREMENTS
Passenger Information Amenities Passenger information that can be provided at stations includes system name, system brand, route name or number, station name, route map, route hours or schedule, neighborhood map, and system map. Variable message signs can be used to display real-time arrival estimates or special notices.	 *Customer Information Display at bus stop in Boston*	• Passenger information at a station is one of the basic means of communication between the transit agency and its customers. Accurate and complete information helps customers make appropriate decisions about transit trips and helps reduce anxiety.	• Maintenance is required to make sure that the information is correct, current, and free of dirt and graffiti.
Passenger Comfort and Convenience Amenities Passenger amenities that increase physical comfort include newspaper boxes, drink and fare vending machines, trash containers, heating, cooling, and public telephones, as well as high-quality station and shelter materials and finishes, public art, and landscaping.	 *Decorative tile flooring at a bus stop along the Orange Line*	• Amenities can improve passenger comfort, particularly the quality of the experience while waiting, which is frequently the least enjoyable part of the transit trip. High-quality amenities can attract customers and improve the image of transit.	• Amenities add both capital and maintenance costs. Poorly-maintained, non-functioning amenities do not improve the image of public transit.
Passenger Security/Amenities Passenger safety and security amenities include station lighting, public address systems, emergency telephones, alarms, and video camera monitoring (often through closed circuit television).	 *Passenger Security Phone at bus stop*	• To improve safety and security, both actual and perceived.	• Passenger security amenities require institutions to support and enforce security as well as ongoing maintenance.

Curb Design

Curb design affects the vertical and horizontal gap between the BRT vehicle and the platform. The Americans with Disabilities Act (ADA) Design Guidelines specify a maximum horizontal and vertical gap between vehicle and platform for new rail transit, but not for bus transit. The guidelines for rail state that the

rail-to-platform height in new stations shall be coordinated with the floor height of new vehicles so that the vertical difference, measured when the vehicle is at rest, is within plus or minus 5/8 inch under normal passenger load conditions. For rapid rail, light rail, commuter rail, high speed rail, and intercity rail systems in new stations, the horizontal gap, measured when the new vehicle is at rest, shall be no greater than 3 inches (Americans with Disabilities Act Design Guidelines, *http://www.access-board.gov/adaag/html/adaag.htm#tranfac*).

To provide rail-like service, BRT planners can seek to meet these guidelines. Reducing the vertical gap can be achieved by raising the platform height. Raised platforms can be used only where buses have a reasonably straight approach to the station. If a station is on a curving approach, some doors will be left with a wide horizontal gap. Tactile platform edges should be applied on any bus platform edge higher than 8 inches.

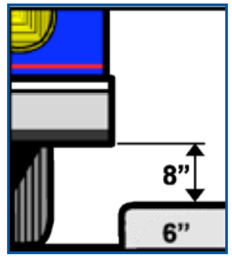
Platforms higher than the standard height should be adopted when horizontal gaps can be reduced. Eliminating the vertical gap (by installing raised platforms) without ensuring that the horizontal gap has been eliminated at all doors is counterproductive. If the horizontal gap is too great, passengers will need to step from a raised platform to the street and then from the street onto the bus, producing considerably greater difficulty than standard height curbs. One approach to ensure that the horizontal gap is eliminated is to use a lateral guidance system, as described in the previous Running Ways section. Without a guidance system, it is necessary to use a sloped curb. Horizontal gaps most often occur because bus operators are trained to avoid expensive damage to tire sidewalls by avoiding contact with the curb; thus, they stay at least a few inches from the curb, and sometimes more. With a sloped curb, operators can be trained to approach closely without producing damage to the side of the vehicle.

Curb Design

Standard Curb Height

The standard curb causes a vertical gap between the height of the station platform or the curb and the vehicle entry step or floor. The gap requires customers to step up to enter the BRT vehicle and step down to exit.

COST: $0



REASONS TO IMPLEMENT

- This is the standard curb height; it must be used if an existing curb will not be modified.
- Allows buses to sweep over curb and sidewalk without damage, facilitating bus maneuvers in tight geometries.

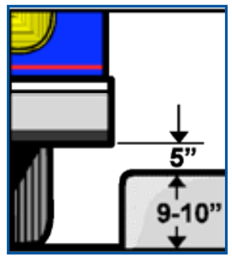
CONSIDERATIONS/ REQUIREMENTS

- The step between curb and vehicle floor may delay boarding and alighting.
- The vertical gap between curb and vehicle requires the use of buses with lifts or ramps to serve wheelchair passengers.

Raised Curb

A raised curb reduces the vertical gap between the platform and the vehicle floor while providing room for a fold-out wheelchair ramp. The raised curb platform height should be no less than 12 inches above the height of the street or other running way. The raised curb will more closely match the height of BRT vehicle's entry step or floor to accommodate near-level boarding.

COST: Requires an additional 6 inches of concrete depth.



REASONS TO IMPLEMENT

- Reduces boarding time by facilitating boarding for walking passengers and reducing the likelihood of deploying kneeling or ramps. A curb a few inches below the bus floor provides room for the thickness of a fold-out ramp. A vertical gap greater than 5/8-inch does not meet ADA Design Guidelines for rail transit.

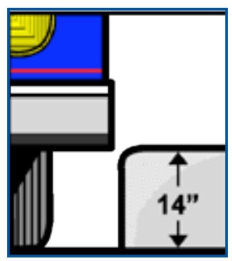
CONSIDERATIONS/ REQUIREMENTS

- Platform must be newly-built or reconstructed and requires reconfiguration of sidewalk infrastructure.

Level Curb

Platforms level with vehicle floors (approximately 14 inches above the pavement for low-floor vehicles) facilitate boarding for wheelchairs, strollers, wheeled luggage, and people with mobility impairments and reduce boarding and alighting delay.

COST: Requires an additional 8 inches of concrete depth.



REASONS TO IMPLEMENT

- Only this option will fully meet the ADA Design Guidelines standard for rail vehicles.
- Level curbs reduce boarding time.

CONSIDERATIONS/ REQUIREMENTS

- Platform must be newly-built or reconstructed and requires reconfiguration of sidewalk infrastructure.
- Must be sufficient room to taper platform to height of normal curb.
- If no guidance system, a sloped curb must be used to permit drivers to come close enough so that wheelchair boarding is possible without the use of a ramp.

Sloped Curb

A smooth curb sloped correctly will prevent the base of the bus tire from scuffing the sidewall while still preventing the bus body from contacting the curb. Precast concrete curbs are sold overseas specifically for this purpose (Brett and Charcon xxxx). However, curbs with such a profile can also be poured in place, the construction method used in most regions of the U.S. Existing BRT systems with sloped curbs include the Las Vegas MAX BRT, which was intended to use optical guidance to provide precision docking in connection with its raised platforms. The Eugene EmX uses smooth plastic edging to allow drivers to achieve precision docking at its raised platforms.

Precast section of sloped curb with marker bump (Charcon)

REASONS TO IMPLEMENT

- Allows drivers to position bus tires against curb without scraping bus body, thereby enabling a minimal horizontal gap without damage to the bus. No special guidance systems are required.

CONSIDERATIONS/ REQUIREMENTS

- Curb must be newly installed. Drivers need to be trained to make contact with this special curb, which is contrary to their standard operating procedure.

Platform Layout

Platform layouts range from single-vehicle-length with a single berth (bus position), usually from 50 feet where only conventional 40-ft buses are used, to as long as 300 or more feet where multiple articulated buses can be accommodated.

Platform Layout

		REASONS TO IMPLEMENT	CONSIDERATIONS/ REQUIREMENTS
Single-Vehicle-Length Platform A single vehicle length platform is the shortest platform length necessary for the entry and exit of one BRT vehicle at a time at a station.	 *Single length platform on Miami-Dade transitway*	• Minimizes required space and cost, especially on streets where driveways and storefronts limit available platform space.	• If more than one bus arrives at a time, the second bus may have to wait for the first bus; this problem can be minimized by coordinating the schedules of multiple routes serving the same station and by taking appropriate measures to reduce bunching.
Extended Platform with Unassigned Berths Extended platforms usually accommodate no less than two vehicles and allow multiple vehicles to simultaneously load and unload passengers. **COST**: Incremental cost will be a multiple of a single-vehicle-length platform based on the maximum number of vehicles accommodated.	 *Extended bus platform on Miami-Dade Transitway*	• Since more than one vehicle at a time can be accommodated, multiple routes or local and express service or vehicles that have become bunched can more easily use BRT stations and running ways.	• If on a street, can necessitate the loss of more on-street parking. • With unassigned bays, multiple buses boarding simultaneously can be problematic. Passengers must run up and down the platform to find their bus. Dynamic signs can be installed telling passengers in advance what position (or berth) their bus will be located.
Extended Platform with Assigned Berths Extended platforms with assigned berths have all 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. **COST**: Incremental cost will be a multiple of a single-vehicle-length platform based on the maximum number of vehicles accommodated.	 *Extended bus platform with assigned berths on Miami-Dade Transitway*	• Generally used at major transfer areas or centers, such as where bus routes are feeding an express route or rail rapid transit. • Easier for passengers to understand where to board if multiple routes serve the same stations.	• Can take a significant amount of space, and is generally not suitable for on-street locations. • Requires passing capability at stations

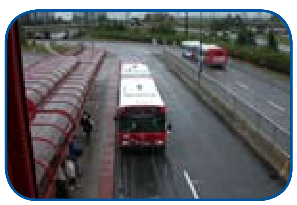
Passing Capability

On busways or expressways with on-line stations, the ability of BRT vehicles to pass one another at stations is especially important for at least three reasons:

- in mixed flow operation, where travel times are highly variable
- in cases where multiple types of routes (local and express) operate along the same running way and serve uneven levels of demand or where buses operate at short headways
- where BRT vehicles operate at high frequencies

In both cases, BRT vehicles can delay others operating on the same running way if there is no ability to pass.

Passing Capability

		REASONS TO IMPLEMENT	CONSIDERATIONS/ REQUIREMENTS
Bus Pull-Outs For both arterial BRT operation and exclusive lanes, bus pull-outs at stations allow buses to pull out of the BRT running way, and thus out of the way of BRT vehicles that need to pass vehicles stopped at the stations. The bus must yield to traffic when returning to the travel lane, sometimes resulting in substantial delay. Cost: \$0.05 million - \$0.06 million per pull-out (per station platform)	 *Bus pullout at stop in New Zealand*	• Most appropriate solution for on-street locations where it is expected that other buses, or general traffic, will be passing the stopped bus.	• The need for BRT vehicles to merge into traffic may motivate the need for a "yield to bus" law in the local jurisdictions.
Passing Lanes at Stations Passing lanes at stations allow a vehicle in express service to pass through a station at full speed or a vehicle to overtake stopped buses. Cost: \$2.5 - \$2.9 million per lane mile (excluding ROW acquisition)	 *Passing lane at station in Ottawa*	• Permits flexible operating plans such as express service and skip-stop service, permits late vehicles to return to schedule, and facilitates emergency vehicle use of a transitway. • Promotes move reliable service, reducing congestion and queues at stations.	• Requires greater right-of-way width. The amount of cross-section needed for a passing lane can be minimized by staggering the stations serving opposite directions so they are not directly across from each other.

Station Access

When designing off-street transit stops, it is important to consider pedestrian access from adjacent sites as well as connections through the roadway network to adjacent neighborhoods by automobile or non-motorized modes. Consideration should also be given to parking and drop-off.

Station Access

Pedestrian Linkages

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

Cost: Typically included in the base cost for designated stations and intermodal terminals or transit centers.

Pedestrian linkage to shopping center in Ottawa from transit station

REASONS TO IMPLEMENT

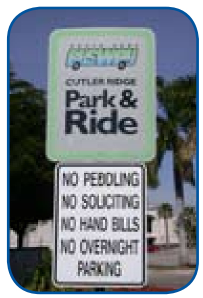
- Direct links to buildings or weather-protected passageways provide more attractive access for passengers.

CONSIDERATIONS/ REQUIREMENTS

- Developing attractive pedestrian linkages requires coordination with adjacent land uses and property owners.

Park-and-Ride Facilities

Park-and-ride lots allow stations, including those without significant development, to attract passengers from a wide area around BRT stations. Because BRT services can be easily routed off their primary running way, regional park-and-ride facilities need not be adjacent to the primary BRT running way. This arrangement can link BRT service with existing parking lots, potentially reducing capital investment costs.



Park-and-ride signage

REASONS TO IMPLEMENT

- Provides access to BRT for those not near the BRT line or stations.

CONSIDERATIONS/ REQUIREMENTS

- Surface parking adjacent to BRT stops can deter pedestrian access and limit opportunities for development.
- Parking structures are more compact, but greatly add to the construction costs.
- Facilities located away from a transitway may require buses to leave the transitway for a considerable distance, thus slowing service for through riders.

Effects of Station Elements on System Performance and System Benefits

Exhibits 2-3A and 2-3B summarize the links between station elements and the BRT performance indicators and system benefits identified in Chapter 1. These links are explored further in Chapters 3 and 4.

Exhibit 2-3A: Summary of Effects of Station Elements on System Performance

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Station Location and Type • On-Street, No Shelter • On-Street, Simple • On-Street, Enhanced • Off-Street, On-Line Station • Off-StreetTransit Center	Stops adjacent to the running way minimize delay from circuitous routing. Transit centers can reduce wait and transfer times between transit services. Off-street or off-line stations may increase transfer times to other transit services.		More distinct stations enhance the system's brand identity and present a "high quality" image. Sta-tions can be architecturally noteworthy spaces, especially station buildings. On-street stations should complement and enhance public street-scapes. Off-street stations may mitigate noise and vibration impacts. They also provide opportunities for landscaping and sound walls.	Off-street stations may raise safety concerns if they are isolated from pedestrian and motor traffic. Transit centers and larger stops concentrate activity and thus make bus stops feel safer. On-street stations need to protect pas-sengers from motorists. Station designs can en-hance security by using transparent materials and ensuring good sightlines.	Larger stations increase loading capacity.	On-street station locations, especially those where station plat-forms are adjacent to street curbs, tend to have easier access. More complex station types – station enclosures, station build-ings, and intermodal terminals or transit centers – tend to re-quire additional de-sign attention to ensure barrier-free access and ease of entry and transfers.
Passenger Amenities •Information •Comfort and Convenience •Security	Complete, accurate, and up-to-date information reduces real and perceived waiting time.	Real-time info may provide perception of reliability.	Amenities make customers feel comfortable and well-served. They can reinforce a high quality image.	Lighting, video surveillance, and positive image contribute to safety.		Information amenities such as maps and real-time informa-tion can incorporate accommodations for people with vision and people with hearing impairments (real-time variable message signs).
Curb Design • Standard Curb Height • Raised Curb • Level Curb • Sloped Curb	Reduced vertical and horizontal gaps facilitate boarding and reduce dwell time.	Reduced vertical and horizontal gaps facilitate boarding and reduce dwell time variability, particularly if wheelchair ramps are not required.	Level platforms present an image of advanced technology, similar to rail.	Minimizing vertical and horizontal clearance may reduce tripping during boarding and alighting and may facilitate faster unloading during an emergency.	Reduced dwell times resulting from faster level boarding increase station throughput.	Curb designs that minimize the vertical gap between station platform and vehicle floors facilitate boarding for all groups. Level boarding treatments allow for people using wheelchairs to board without ramps. Use of detectable warning strips at boarding and alighting demarcations is an effective limit setting measure and provides delineators of the station areas.

Exhibit 2-3A: Summary of Effects of Station Elements on System Performance (cont'd.)

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Platform Layout • Single Vehicle Length • Extended with Unassigned Berths • Extended with Assigned Berths	Allowing multiple vehicles to load and unload facilitates lower station clearance time.	Allowing multiple vehicles to load and unload reduces potential delays.	Long platforms with unassigned berths create confusion for passengers.		Longer platforms limit queuing delays for vehicles waiting to load and permit a variety of service options.	Platform layouts with assigned and well-signed berths create a system that it is easy to understand and navigate.
Passing Capability • Bus Pullouts • Passing Lanes at Stations	Passing at stations allows for express routes and minimizes delays at stations. Bus pullouts in mixed traffic situations lead to delays.	Passing at stations allows for schedule maintenance and recovery.			Passing capability limits queuing delays at stations and permits a variety of service options.	
Station Access • Pedestrian Linkages • Park-and-Ride	Reduced vertical and horizontal gaps facilitate boarding and reduce dwell time.		Treatments to high-light station access make transit seem open, welcoming, and easy to use.	Better pedestrian linkages facilitate integration with communities.		Good integration to surrounding infrastructure, especially pedestrian linkages, allows barrier-free access to/from the station and between transit elements and modes.

Exhibit 2-3B: Summary of Effects of Vehicle Elements on System Performance

	Higher Ridership	Capital Cost Effectiveness	Operating Cost Efficiency	Transit-Supportive Land Development	Environmental Quality
Station Location and Type • On-Street, No Shelter • On-Street, Simple • On-Street, Enhanced • Off-Street, On-Line Station • Off-StreetTransit Center	Stations that are well-located and comfortable will maximize ridership, regardless of their type. Smaller stations may reduce capacity, thus limiting ridership. Larger, more distinctive or more attractive stations may increase ridership by enhancing the system brand and image.	Off-street stations may have significant costs for infrastructure and land acquisition.	Off-street stations will have significant maintenance costs.	Off-street stations create greater opportunities for station-area development. More substantial stations may attract developers by demonstrat-ing permanence and by improving the appearance of the streetscape. On-street stations should be designed to complement the streetscape. Large median stations can be a visual barrier to crossing the street, which is desired for devel-opment in urban environ-ments.	Off-street stations will re-quire environmental permitting. Stations adjacent to highways can act as buffers between high-ways and neighbor-hoods. Traffic noise at the station may be a concern.
Passenger Amenities •Information •Comfort and Convenience •Security	Passenger comfort and informa-tion can shape perceptions of the service and thus have a large effect on use. Passenger information may attract riders by making the sys-tem easier to use.	Costs are very low compared to all other aspects of infrastructure.	Keeping facilities clean and information up-to-date requires a commitment to maintenance.	Affects primarily through-service quality. Security is important to attracting developer interest.	Affects only through-service quality.
Curb Design • Standard Curb Height • Raised Curb • Level Curb	May affect ridership by reducing dwell time and improving convenience.	If system design calls for new or rebuilt curbs, there is a modest additional cost associated with building a raised, level, or sloped curb rather than standard.	Reduced dwell time reduces operating cost.	Affects only through-service quality. A raised curb in a median lane can inhibit pedestrians crossing the street, which is desired for development in urban environments.	Affects only through-service quality.

Exhibit 2-3B: Summary of Effects of Vehicle Elements on System Performance (cont'd.)

	Higher Ridership	Capital Cost Effectiveness	Operating Cost Efficiency	Transit-Supportive Land Development	Environmental Quality
Platform Layout • Single Vehicle Length • Extended with Unassigned Berths • Extended with Assigned Berths	Extended platforms can increase system capacity, which affects total ridership.	Land costs are largest factor.	Increased flexibility of multiple berths may reduce operating cost.		Many berths requires more impervious surface.
Passing Capability • Bus Pullouts • Passing Lanes at Stations	Passing increases system capacity, which affects total ridership.	Modest increase in cost.	Increased flexibility may reduce operating cost.		Can decrease station dwell time and reduce emissions.
Station Access • Pedestrian Linkages • Park-and-Ride	Making walking, cycling, and motoring access quicker and more pleasant reduces a significant cost of transit, and thus will increase ridership.	Ranges from minimal (covered walkway) to high (parking structure).		Close walking access to adjacent development sup-ports TOD. Park-and-ride lots can limit TOD opportunities around stations.	Higher car use to access transit reduces air quality and energy benefits of transit.

Implementation Issues

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

Implementation Issues During Project Development

Availability of Property

Just as the availability of right-of-way is an issue in the implementation of running ways, the availability of physical property for stations is a key factor in station planning. On-street BRT routes using curb lanes (either general purpose lanes or exclusive bus lanes) typically serve stations sited on existing sidewalks. Clearance for pedestrian and wheelchair traffic must be accounted for in the design of stations on public sidewalks. In some cases, additional street right-of-way is required through either partial lane realignment or a sidewalk extension ("bulb-out"). Planners must balance the needs of parking, general traffic lanes, and BRT stations. In exclusive running way sections, additional real estate is required to build full stations. In some cases, station platforms must fall on opposite sides of the street due to right-of-way constraints.

Pedestrian Access and Safety

Care must be taken to minimize potential conflicts between pedestrians and BRT vehicles in and around stations. The need to develop a strong linkage for pedestrians (including those using wheelchairs) to adjacent communities will affect the site layout for BRT stations. Because station platforms typically are not much higher than the running way through the station, pedestrians may attempt to cross to the other side, risking a collision with an oncoming BRT vehicle. Conflicts between pedestrians and BRT vehicles may occur at crossings between BRT running ways and cross streets. Some BRT designs incorporate elements that minimize this conflict. For example, the Southeast Busway in Brisbane, Australia provides elevated passageways that are used to provide access to stations.

Community Integration

As the primary starting point for a transit trip, stations provide the first impression of the transit system and are the primary link between the system and its surrounding community. Station design and pedestrian linkages to the surrounding community are critical in conveying an identity for the BRT system. Two key considerations are important to consider in designing stations to integrate with the community:

- ***Landscaping and Public Art***—BRT system integration into an urban setting provides an opportunity to beautify the areas around running ways and stations with landscaping and other upgraded amenities such as lighting, sidewalks, street furniture, and public art including statues and other art objects.

- ***Planning and Zoning***—Planning guidelines and zoning regulations define the intensity and character of the existing and potential development around a station. It is important, therefore, to ensure that planning and zoning laws permit stations, or future stations, to be integrated with transit-supportive development. Good transit service and higher densities tend to go together. Higher density development, particularly development designed with transit use in mind, will result in higher transit use. More transit ridership, in turn, supports better transit service.

Advertising

Transit agencies often permit advertising on their facilities to earn additional revenue. BRT station design that incorporates provisions for print or electronic advertising can enhance revenue generation for the operating agency. Some transit agencies have contracted with firms that provide transit shelters in exchange for advertising revenues.

Implementation Issues During Operation

Security

Station plans should account for the possibility of crime or other security threats. Common ways of deterring crime include a high level of general lighting, surveillance cameras and equipment, emergency call boxes, closed-circuit television monitoring, extensive spot illumination, and the use of transparent materials such as glass. Passive ways of incorporating security into the design focus on openness, high visibility, and intense lighting. Unobstructed sight lines enable BRT customers to view their surroundings and be viewed within and outside of the facility.

Experience with BRT Stations

Exhibit 2-4 summarizes station characteristics found in over 50 BRT lines or systems operating in 37 cities around the world.

With U.S. BRT systems, all station and stop types are well-represented, with almost all instituting a station design that provides a significant upgrade from standard bus service stops. Several U.S. systems use multiple station design types, either because the BRT running way incorporates several different configurations or because the station must visually complement a variety of streetscape environments. Few feature fully enclosed stations as the primary station design. Approximately one-third of the U.S. BRT lines included in Exhibit 2-4 use simple stations, and another third use enhanced stations. Roughly half incorporate at least one off-street station or transit center; these may be enclosed, such as with the Boston Silver Line, but most are not. The least-used option is the basic stop, with only around one-quarter using this option, and most using it combination with more substantial station infrastructure.

Most U.S. BRT stations offer at least a basic level of passenger amenities such as route maps, schedule information, seating, and trash containers. Off-street BRT systems with more complex stations, such as in Pittsburgh and Los Angeles, include additional amenities such as seating, public address systems, heating, and emergency telephones. Most U.S. stations still use standard height curbs; this is a function of the dominance of on-street, mixed traffic operations among U.S. BRT systems. Several cities that built dedicated guideways (both on and off-street) have installed raised or near-level platforms, such as Cleveland and Eugene. Only a few systems feature multiple vehicle berths or passing capability. Several systems with extensive suburban operation have park-and-ride lots, including Los Angeles, Miami, and Pittsburgh.

Outside the U.S., more substantial stations, often enclosed, are common, as a function of the greater use off-street, dedicated running ways. Overall, BRT applications outside the U.S. are much more likely to feature raised platforms or level boarding; multiple bus berths; and passing lanes in stations. It appears to be less common outside the U.S. to build park-and-ride lots, except for Australia's BRT applications.

Exhibit 2-4: Experience with BRT Stations

	Albuquerque	Boston Silver Line				Chicago		
	Rapid Ride - Red Line	Washington Street	Waterfront: Airport	Waterfront: BMIP	Waterfront: City Point	Western Avenue Express	Garfield Express	Irving Park Express
Station Location and Type (total in both directions)								
On-Street								
• No Shelter		4	5			80	36	38
• Simple		1		8	14			
• Enhanced	28	16						
Off-Street Station			4	4	4			
Transit Center	2	1						
Amenities								
Telephone								
Restroom								
Vending								
Seating								
Trash Container		X						
Temperature Control								
Public Art								
Public Address								
Emergency Telephone		X						
Security Monitoring (CCTV / Police Presence)								
Platform Height and Length								
Curb Design	Standard curb	Standard curb	Standard curb			Standard curb		
Maximum Vehicles Accommodated	1	1	1 above ground, 3 underground			1	1	1
Passing Capability	-	-						
Park-and-Ride Lots	2	0	226 parking spaces at South Station; street & private lots elsewhere			0	0	0

Exhibit 2-4: Experience with BRT Stations (cont'd.)

	Cleveland	Eugene	Honolulu			Kansas City	Las Vegas	Los Angeles	
	Healthline	EmX	Route A: City Express!	Route B: City Express!	Route C: Country Express!	MAX - Main St	Metropolitan Area Express (MAX)	Orange Line	Metro Rapid (All Routes)
Station Location and Type (total in both directions)									
On-Street									
• No Shelter									496
• Simple			69	57	81		2		
• Enhanced	36	16				42	18		116
Off-Street Station		2						26	
Transit Center							2	2	38
Amenities									
Telephone								X	
Restroom									
Vending							Beverages		
Seating		X	X	X			X	X	
Trash Container							X	X	X
Temperature Control									
Public Art		X						X	
Public Address									
Emergency Telephone								X	
Security Monitoring (CCTV / Police Presence)								X	
Platform Height and Length									
Curb Design	Near level	Raised curb	Standard curb	Standard curb	Standard curb	Raised curb	Raised curb	8" curb	Standard curb
Maximum Vehicles Accommodated	1 40' + 1 60'		1	1	1	1	1	3 60' (200')	1
Passing Capability	No	No				Bus pullouts		Passing lane at each in-line station	
Park-and-Ride Lots	None		None	None	None		None	7 lots	None

Exhibit 2-4: Experience with BRT Stations (cont'd.)

	Miami		Oakland	Orlando	Phoenix			
	South Dade Busway MAX	Busway Local	San Pablo Ave Rapid	LYMMO	RAPID - I-10 East	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17
Station Location and Type (total in both directions)								
On-Street								
• No Shelter								
• Simple								
• Enhanced			52		24	18	24	26
Off-Street Station	30	16		22				
Transit Center								
Amenities								
Telephone	X	X						
Restroom								
Vending								
Seating	X	X	X		X	X	X	X
Trash Container	X	X	X					
Temperature Control								
Public Art								
Public Address								
Emergency Telephone	X	X						
Security Monitoring (CCTV / Police Presence)								
Platform Height and Length								
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb
Maximum Vehicles Accommodated	3	3	1	2	1	1	1	1
Passing Capability	Bus pullouts	Bus pullouts			Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts
Park-and-Ride Lots	None		None	None	None		None	None

Exhibit 2-4: Experience with BRT Stations (cont'd.)

	Pittsburgh			Sacramento	San Jose	Santa Monica	Halifax	Ottawa
	East Busway (All Stops)	South Busway	West Busway (All Stops)	EBus - Stockton	Rapid 522	Lincoln Rapid	MetroLink (All Routes)	Transitway (All Routes)
Station Location and Type (total in both directions)								
On-Street								
• No Shelter				19	19			
• Simple				14	33	28	6	0
• Enhanced				0	4			6
Off-Street Station	16	16	12	0	0		6	28
Transit Center	2	2	2	2	4		4	34
Amenities								
Telephone		X						
Restroom								
Vending								
Seating	X	X	X					
Trash Container	X	X	X					
Temperature Control	X	X	X					
Public Art								
Public Address	X	X	X					
Emergency Telephone	X	X	X					
Security Monitoring (CCTV / Police Presence)								
Platform Height and Length								
Curb Design	Raised curb	Raised curb	Raised curb		Standard curb	Standard curb	Standard curb	Standard curb
Maximum Vehicles Accommodated					2	1	2	3
Passing Capability	Passing allowed	Passing allowed	Passing allowed	None	None	None	None	Bus pullouts
Park-and-Ride Lots	16	12	10		3 with 281 spaces; 3 with 1300 spaces at commuter rail stations	None	6	8

Exhibit 2-4: Experience with BRT Stations (cont'd.)

	York	Bogotá	Guayaquil	Pereira	Amsterdam	Caen	Edinburgh	Eindhoven
	VIVA (All Routes)	Transmilenio	Metrovia	Megabus	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor
Station Location and Type (total in both directions)								
On-Street								
• No Shelter								
• Simple								
• Enhanced						30		
Off-Street Station	8	234	68	70		4		
Transit Center	8	26	4	4		1		
Amenities								
Telephone								
Restroom								
Vending								
Seating								
Trash Container								
Temperature Control								
Public Art								
Public Address								
Emergency Telephone								
Security Monitoring (CCTV / Police Presence)								
Platform Height and Length								
Curb Design	Standard curb	Level platform	Level platform	Level platform	Level platform	Level platform	Level platform	Level platform
Maximum Vehicles Accommodated	1	2 to 5		1 to 2				
Passing Capability	Bus pullouts	Bus pullouts at many stations; some lines more than 2 lanes.	No passing	No passing				
Park-and-Ride Lots	None	None	None					

Exhibit 2-4: Experience with BRT Stations (cont'd.)

	Leeds	London	Rouen	Utrecht	Adelaide	Brisbane	
	Superbus	Crawley	TEOR	Busway	North East Busway	South East Busway	Inner Northern Busway
Station Location and Type (total in both directions)							
On-Street							
• No Shelter		62	52	13			
• Simple							
• Enhanced							
Off-Street Station					3 in each direction	27 in each direction	27 in each direction
Transit Center							
Amenities							
Telephone							
Restroom							
Vending							
Seating							
Trash Container							
Temperature Control							
Public Art							
Public Address							
Emergency Telephone							
Security Monitoring (CCTV / Police Presence)							
Platform Height and Length							
Curb Design	Level platform, raised curb	Standard curb	Level platform	Level platform	Standard curb	Standard curb	Standard curb
Maximum Vehicles Accommodated					3- and 4-bus length	Standard 4; max 5	
Passing Capability	No passing in guideway		No passing	No passing	Passing at interchanges	Bus pullouts	Bus pullouts
Park-and-Ride Lots	1 park-and-ride, 179 spaces				3; total vapacity is 1,190	2 stations; total of 759 spaces	None designated

Exhibit 2-4: Experience with BRT Stations (cont'd.)

	Sydney			Beijing	Hangzhou	Kunming
	Liverpool-Parramatta T-Way	North-West T-Way Blacktown-Parklea	North-West T-Way Parramatta-Rouse Hill	Line 1	Line B1	Busway Network
Station Location and Type (total in both directions)						
On-Street						
• No Shelter						
• Simple	22		2			
• Enhanced	4		4		32	
Off-Street Station	40			38		
Transit Center	4	11 in each direction	18 in each direction			
Amenities						
Telephone						
Restroom						
Vending						
Seating						
Trash Container						
Temperature Control						
Public Art						
Public Address						
Emergency Telephone						
Security Monitoring (CCTV / Police Presence)						
Platform Height and Length						
Curb Design	Standard curb	Standard curb	Standard curb	Level platform	Standard curb	Standard curb
Maximum Vehicles Accommodated	Standard 2 bus, Max 6 buses	Standard 2 bus, 4 at termini				60 m platform length
Passing Capability	Bus pullouts at stations	Bus pullouts at stations	Bus pullouts at stations	Multiple lanes	Multiple lanes	None
Park-and-Ride Lots	1 designated	None designated	2 designated; 300 spaces			

VEHICLES

Description

Role of Vehicles in BRT

BRT vehicles have a direct impact on speed, capacity, environmental friendliness, and comfort, both actual and perceived.

Vehicles are also the BRT element in which customers spend the most time, and one of the system elements that is the most visible to non-customers. Therefore, much of the public impression of the BRT system comes from experience with vehicles. Because of this, vehicles are also the element of BRT that most passengers and non-customers associate with the BRT system's identity. They can play an important role in successful branding.

Characteristics of Vehicles

Four primary attributes define BRT vehicles:

- ***Vehicle Configuration***—The physical configuration of BRT vehicles combines size, floor height, and body type. Transit vehicles in the United States have traditionally been high-floor vehicles with steps. In response to ADA, low-floor vehicles have become common in conventional transit operations. This is an evolutionary step that benefits bus service generally, and BRT in particular. Vehicles in most U.S. BRT applications range from low-floor, two-axle, 40- or 45-ft units to three-axle, 60-ft articulated buses. Both shorter and longer platforms may eventually find their way into the domestic BRT market, with shorter vehicles (25- to 30-ft) and longer vehicles (e.g., bi-articulated vehicles) possibly figuring in specific future deployments.
- ***Aesthetic Enhancement***—Aesthetic treatments, including paint schemes and styling options that affect the appearance and configuration of the vehicle body and contribute to BRT system identity. They help to position BRT as a quality option and provide information to potential customers as to where to access BRT services. Manufacturers have responded to market demand for more stylized vehicles, offering visually appealing windshield and window treatments as well as other exterior styling cues that suggest a rail-like quality. Interior amenities such as high-quality materials, better and more energy-efficient lighting, climate control, and sound reduction also contribute to customer perception of comfort and service quality.
- ***Passenger Circulation Enhancement***—Several enhancements can be added to vehicles to expedite passenger boarding and alighting as well as circulation within the vehicle. The provision of additional and/or wider door channels, including median (left-side) doors, can improve circulation, as can various seat layouts, including those allowing for wider aisles, and alternative wheelchair securement positions.
- ***Propulsion/Fuel***—Fuel propulsion systems determine the acceleration, maximum speed, fuel consumption, and emissions characteristics of BRT vehicles. Propulsion options, particularly hybrid and electric propulsion systems, can also affect the sound levels inside and outside the bus, as well as impact operating and maintenance costs. Smooth acceleration and quiet operation associated with electric drivetrains may contribute to the perception of BRT as an upgraded mode of travel, potentially attracting additional riders. Alternative fuels, including natural gas and hydrogen/natural gas blends, can favorably impact emissions, but also may affect performance and capital costs associated with fueling and maintenance infrastructure.

Vehicle Options

Vehicle Configuration

Vehicle configuration, the primary vehicle planning/design parameter, represents the combination of the length, passenger capacity, body type, and floor height of the vehicle. All of these parameters affect the vehicle's ability to transport passengers efficiently and in reasonable comfort.

BRT systems can use a variety of different vehicle configurations on a single running way or within a broader transit system, with each configuration tailored to a specific service profile and market. Los Angeles has both 45-ft buses and 60-ft articulated buses running in mixed traffic along some high-ridership corridors, though in its dedicated running way, 60-ft articulated vehicles are used exclusively. The Ottawa and Miami-Dade systems also illustrate flexibility in BRT fleet vehicle mix by running way type. BRT's inherent flexibility does allow communities to launch service in phased deployments, beginning with standard 40- to 45-ft vehicles with a plan to transition or supplement with 60-ft articulated buses as demand grows.

While local transit services and some BRT systems—including the highly effective systems in Bogotá, Columbia and Curitiba, Brazil—use high-floor buses (corresponding to high station platforms), the options presented here represent those options primarily available to the North American market. Many North

American transit agencies are moving toward the low-floor platform for regular as well as BRT service.

Vehicle Configuration

Conventional Standard

Conventional standard vehicles are 40 to 45 ft in length and have a conventional ("boxy") body. The partial low-floor variety (now the norm among urban transit applications) contains internal floors that are significantly lower (14 inches above pavement) than high floor buses. They typically have at least two doors and a rapidly deployable ramp for wheelchair-bound and other mobility-impaired customers.

Capacity:

A typical 40-ft vehicle has seating for 35-44 patrons, expanding to between 50 and 60 seated and standing.

A typical 45-ft vehicle can carry 35-52 passengers seated and 60-70 seated and standing.

COST: $375,000 to $400,000

Conventional Standard bus—Metro Rapid

REASONS TO IMPLEMENT

- Due to high volume of production, these standard buses usually offer the lowest unit price in terms of acquisition costs.
- Consistency with the rest of the fleet facilitates interchangeability and ease of maintenance.

CONSIDERATIONS/ REQUIREMENTS

- Capacity is limited and, in peak periods, more buses are required, which impacts operational costs in terms of maintenance, fuel, and labor.
- No major impact for standard maintenance practices since most transit operations include this vehicle configuration.

Stylized Standard

Stylized standard vehicles have the features of a conventional step low-floor vehicle but they also incorporate slight body modifications or additions to make the body appear more modern, aerodynamic, and attractive.

Capacity:

Similar to Conventional Standard vehicles of the same size.

COST: $425,000 to 450,000

Stylized Standard bus—Metro Rapid

REASONS TO IMPLEMENT

- Incremental styling changes provide some aesthetic and functional differentiation of service.

CONSIDERATIONS/ REQUIREMENTS

- May require alternative procurement methods.
- May be more expensive than conventional buses.

Conventional Articulated

The longer, articulated vehicles have a higher passenger carrying capacity (50% more) than standard vehicles. Typical floors are partial low floors with steps with two or three doors.

Capacity:

Articulated vehicle seating capacity depends heavily on the number and placement of doors, ranging from 31 (four wide doors) to 65 (two doors) and total capacity of 80-90 passengers, including standees.

COST: $700,000 to $750,000

Conventional Articulated—Silver Line

REASONS TO IMPLEMENT

- Higher capacity can absorb more peak passenger volume, provide more space and passenger comfort.

CONSIDERATIONS/ REQUIREMENTS

- Some limitations on routing because of length.
- May require modifications to maintenance facilities to accommodate larger vehicles.

Stylized Articulated (Partial Low-Floor)

Stylized articulated vehicles are emerging in the U.S. to respond to the desires of BRT communities for more modern, sleeker, and more comfortable vehicles. Step-low floors, at least three doors, with two double-stream and quick-deploy ramps facilitate boarding and alighting to shorten stop dwell times.

Capacity:

As with other articulated vehicles, seating capacity depends heavily on the number and placement of doors ranging from 31 (four wide doors) to 65 (two doors) and total capacity of 80-90 passengers, including standees.

COST: $800,000 to $950,000

Stylized Articulated—Orange Line

REASONS TO IMPLEMENT

- Offers the same advantages as conventional articulated vehicles, with the added appeal of stylized exterior and interior design. More easily identified and brandable, differentiating them from regular service vehicles.

CONSIDERATIONS/ REQUIREMENTS

- May require alternative procurement methods.
- Some limitations on routing because of length and turn radius.
- May require modifications to maintenance facilities to accommodate larger vehicles.

Specialized BRT Vehicles (Full Low-Floor)

Specialized vehicles employ a modern, aerodynamic body that has a look similar to that of rail vehicles. Special axles and drivetrain configurations create a full low floor in the vehicle interior. They also employ advanced propulsion systems and often include integrated ITS components and guidance systems.

Capacity:

As with other articulated vehicles, seating capacity depends heavily on the number and placement of doors.

Specialized BRT Vehicle—Translohr

- Incorporate what many perceive as features and amenities needed to provide rail-like experience of top-level BRT vehicles.

- Currently available only from non-American, primarily European, manufacturers.
- Availability of new models is affected by the ability of transit agencies to structure procurement processes and develop fleet orders of sufficient size for manufacturers to respond and invest in the development of specialized BRT models.

Aesthetic Enhancements

Above and beyond the basic vehicle type, several aesthetic enhancements can be added to vehicles to enhance the attractiveness of vehicles to passengers. Selection of these features can have important impact on community and rider acceptance. New features, including streamlined styling, smooth electric propulsion, and upgraded amenities for riders, play a role in attracting riders. Market demand studies suggest that general managers of transit properties, local political and civic leaders, and community and rider groups place high stock in the image of the vehicle (WestStart-CALSTART 2004).

Aesthetic Enhancements

Specialized Logos and Livery

Specialized logos and vehicle livery (an identifying design encompassing color, paing scheme, and logos on the vehicle) are often used to create a specialized identity by establishing a brand and theme that patrons recognize and associate with the positive attributes of the BRT system. Studies suggest that livery and image can improve the perception of passenger wait times.

MAX—Las Vegas, Nevada

REASONS TO IMPLEMENT

- Proper application supports successful branding identification, considered essential in attracting new ridership.

CONSIDERATIONS/ REQUIREMENTS

- Requires coordination with a broader branding campaign. Otherwise, badly conceived or poorly promoted branding campaign can result in rider confusion at worst, and little impact at best.
- Requires a dedicated fleet, which may preclude operations strategies such as interlining and rotating vehicles with local transit service.

Larger Windows and Enhanced Lighting

The incorporation of larger windows (especially on low-floor vehicles) and interior light fixtures that allow for abundant light in day or night to provide an "open feeling" can improve the perception and reality of passenger security. Larger windows for each passenger to see in and out are important for perceived patron security. (Note that some advertising such as "bus wraps" on windows can detract from visibility and interior lighting.)

TEOR—Rouen, France

REASONS TO IMPLEMENT

- Increased passenger experience of comfort and security.

CONSIDERATIONS/ REQUIREMENTS

- Potential slight cost increase in replacement and maintenance.

Enhanced Interior Amenities

Enhanced interior amenities such as more comfortable seating, higher quality materials and finishes, better lighting, and climate control can improve the perception of cleanliness, quality construction, and safety.

Translohr—Clermont, France

REASONS TO IMPLEMENT

- Improved rider experience and amenities can improve perception of BRT service and attract non-traditional transit riders.

CONSIDERATIONS/ REQUIREMENTS

- Enhanced interior materials may be more subject to wear and/or vandalism, increasing maintenance costs.

Passenger Circulation Enhancement

Several features can contribute to accessibility to BRT vehicles and circulation within vehicles. These features can have important impacts on dwell time, capacity, passenger comfort, and community and rider acceptance.

Passenger Circulation Enhancement

Alternative Seat Layouts

Alternative seat layouts can increase the aisle width within the vehicle, increasing the standing capacity of the vehicle as well as providing additional space for passenger circulation. Alternative seat layouts include transverse seating (seating placed against the sides of the vehicle) or "two and one seating." These layouts may also convey an impression of openness and accessibility.

TEOR—Rouen, France

REASONS TO IMPLEMENT

- Properly selected seating can improve circulation, reduce dwell times, and enhance passenger comfort.

CONSIDERATIONS/ REQUIREMENTS

- Requires coordination with the disabled community to determine acceptable seating configuration.
- Impacts to seated passenger capacity may require adjustments to vehicle fleet orders.

Additional Door Channels

Additional door channels on vehicles can improve circulation and facilitate boarding from and alighting to station platforms. There are two types of additional door channels:

- Curb side—Additional door channels and wider doors on the traditional side of the vehicle (right side in North America) facilitate the boarding process by allowing multiple queues of passengers to enter the BRT vehicle at one time.
- Opposite side—Adding doors to the opposite side of the vehicle (left side in North Amerrica) can allow for access from center platform stations in the median of an arterial, and from the curb side on one-way streets. This additional feature improves the flexibility of running ways in which the BRT system can operate and simulates the flexibility of rail systems.

Additional doors on feeder line—Bogotá, Colombia

REASONS TO IMPLEMENT

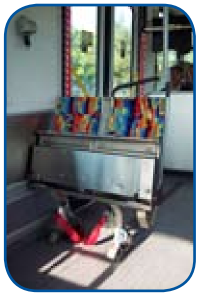
- Adding door channels, particularly in conjunction with low-floor design, can significantly speed passenger access, reducing dwell time and contributing to shorter travel times.

CONSIDERATIONS/ REQUIREMENTS

- Opposite side doors may require additional structural modifications to vehicle orders, potentially raising procurement costs and testing requirements.
- To take full advantage of additional door channels may require alternative fare collection process, such as proof-of-payment enforcement.

Enhanced Wheelchair Securement

Conventional wheelchair securement involves the use of tie-downs, wheel locks, and belts, involving a process that takes between 60 and 200 seconds including boarding time. Alternative wheelchair securement devices are currently being explored to reduce the amount of time to secure wheelchairs in bus operation. In BRT applications, particularly in Europe, rear-facing wheelchair positions and no-gap, no-step boarding and alighting eliminate the requirement for lifts, ramps, and wheelchair securement. The transit agencies in Oakland, California and the York Region in Ontario, Canada have deployed vehicles with this seating configuration. Other types of alternative restraint systems include a four-point belt tie-down system (Kinedyne) and an automated docking system securing the rear of the wheelchair.



Orange Line

REASONS TO IMPLEMENT

- Can speed boarding and alighting of disabled passengers.

CONSIDERATIONS/ REQUIREMENTS

- Prices can vary considerably, as can space available for seated or standing passengers, depending on the technology selected.
- Requires outreach to disabled communities to gain acceptance.

Propulsion Systems

Spurred by the evolution of regulations supporting clean air, the number of choices in vehicle propulsion systems is increasing. Technology is evolving to provide new propulsion systems that use cleaner, alternative fuels and new controls on emissions, resulting in reduced pollution and lower noise emissions. As new technologies are being introduced, market conditions, such as demand and cost of production, are evolving.

Propulsion Systems

Internal Combustion Engines

The internal combustion engine (ICE) fueled by ultra low-sulfur diesel (ULSD) or compressed natural gas (CNG) is the most common propulsion system today. Some transit agencies are testing other fuels such as biodiesel, diesel emulsion blends, and even Liquified Natural Gas (LNG), but these are a small fraction of transit applications. Trials and demonstrations using blends of CNG and hydrogen are yielding encouraging results. Although not yet commercially available, these hydrogen-CNG blends may provide additional emissions benefits. EPA's 2007 and 2010 standards for NOx and PM (particulates) emissions require engines with Exhaust Gas Re-Circulation (EGR) plus exhaust after-treatment technology.

COST: CNG price increment over ULSD is approximately $60,000 per vehicle. Infrastructure capital $700,000 - $1,000,000

Feeder line using Internal Combustion Engine—Transmilenio

REASONS TO IMPLEMENT

- Simplest propulsion system type, requiring almost no adjustment to existing maintenance requirements.
- Lower emissions, potential increases in fuel efficiency, and associated reduction in dependence on fossil fuels. Hydrogen internal combustion engines (HICE) may help encourage hydrogen infrastructure. Biofuels, including biodiesel and biogas, may encourage reduction in dependence on fossil fuels.

CONSIDERATIONS/ REQUIREMENTS

- With the introduction of ULSD and improved combustion and after-treatment, conventional diesel power, without the infrastructure costs, is decreasing interest in the pursuit of alternative fuels, particularly gaseous fuels.
- With the majority of transit fleets using diesel ICEs, conversion to other fuels such as CNG will require conversion of maintenance and fueling facilities.

Trolley, Dual Mode, and Electric Drives

Thermal Electric Drive

Electric trolley bus drives powered by overhead catenary-delivered power are still produced today and are planned in limited quantities for operation in tunnel BRT applications. Dual mode systems with an on-board Internal Combustion Engine (ICE) engine (usually diesel) can operate as a trolley and as an ICE vehicle off the catenary for specialized operations. Also, a hybrid-electric drive, which couples an ICE to a generator, is becoming more commonly used as a drive system in transit vehicles.

Trole electric driven bus—Quito, Ecuador

- The solely electric-powered vehicles offer substantial improvements in emissions reduction over ICE power, as well as higher torque throughout the operating range.
- The dual-mode offers flexibility in systems where some zero-emission operation is required or desired.
- The hybrid-electric drive optimizes the emissions and fuel efficiency of the ICE while offering many of the benefits of the electric drive vehicle.

- For trolley and dual-mode vehicles, installing overhead power systems have significant costs as well as aesthetic drawbacks.

	REASONS TO IMPLEMENT	CONSIDERATIONS/ REQUIREMENTS

Hybrid-Electric Drives

Hybrid-electric drives differ from dual-mode systems in that they incorporate some type of on-board energy storage device (e.g., batteries or ultra capacitors). Though the thermal or internal combustion engines used for hybrid drives are diesel in most transit applications, in a number of cases (e.g., Denver 16th Street Mall vehicles) CNG or gasoline have been used. Fuel economy gains of up to 60 percent are being claimed in urban service. Operational tests show improved range and reliability over ICE buses. Hybrid buses have entered operation in places such as New York and Seattle. More agencies seem to be gravitating to hybrids, and the differential in capital costs seems likely to decline.

COST: Price increment over diesel ICE is $150,000 to $250,000

Hybrid-electric drive bus—Denver, Colorado

REASONS TO IMPLEMENT

- Offers improved performance and fuel economy with reduced emissions (e.g., of nitrogen oxides [NOx] and particulates [PM]).
- Allows for a shift to cleaner propulsion systems without the capital investment in new fueling infrastructure at maintenance facilities. Offers numerous operational advantages over conventional diesel buses, such as smoother and quicker acceleration, more efficient braking, improved fuel economy, and reduced emissions.

CONSIDERATIONS/ REQUIREMENTS

- Some added infrastructure, such as battery conditioners and overhead equipment to service battery tubs, may be required.
- Battery packs are expensive, add weight, and must be replaced periodically during the vehicle's life.
- While hybrids demonstrate lower emissions, current EPA regulations do not yet acknowledge these lower emissions when determining engine compliance.
- Proper maintenance of the battery pack is essential.

Fuel Cells

Fuel cells generate electricity energy through electrochemical reactions in contrast to mechanical power produced by ICEs. Currently, most vehicle fuel cells are hydrogen proton exchange membranes (PEMs) which combine hydrogen and ambient oxygen to produce electricity. Emissions include only oxygen and water.

The United States Department of Transportation sponsors the National Fuel Cell Bus Technology Development Program (NFCPB) to facilitate the development of commercially viable fuel cell bus technologies and related infrastructure. Goals of the NFCBP are to advance technology, reduce production costs, and increase public acceptance of fuel cell vehicles. In addition, there are demonstrations – ongoing and planned – around the world, including California, Connecticut, British Columbia, several European cities, Japan, China, and Brazil.

COST: Currently not commercially available, demonstration vehicles are between $1.5 million and $5 million.

Fuel cells

- Zero emissions and potential reduction in petroleum dependence.
- Reduced vehicle noise.

- Current fuel cell technology cannot approach the lifespan of either current ICE or electric – hybrid or grid-supplied propulsion systems - and replacement cost is considerable.
- Lack of any widespread infrastructure for fueling, the fact that most commercially-available hydrogen is produced from natural gas (a fossil fuel), and lack of demand to motivate investment by manufacturers and fuel suppliers indicates that the technology remains to hold promise, but not in the near term.
- The federal government has not made a significant investment in a hydrogen fueling infrastructure. These investments may be forthcoming in the future.

Effects of Vehicle Elements on System Performance and System Benefits

Exhibits 2-5A and 2-5B summarize the links between the vehicle configuration, appearance, interior design, and propulsion options and the BRT system performance indicators and system benefits identified in Chapter 1. These links are explored further in Chapters 3 and 4.

Exhibit 2-5A: Summary of Effects of Vehicle Elements on System Performance

	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Vehicle Configurations • Conventional Standard • Stylized Standard • Conventional Articulated • Stylized Articulated • Specialized BRT Vehicles • Floor Height	Low floors reduce dwell time delays.	Low floors may reduce variation in dwell time between peak and non-peak hours.	Advanced vehicles present a high-quality image and can appear rail-like. Stylized and articulated vehicles can be easily distinguished from other fleets.	Low floors may diminish tripping hazards.	Larger vehicles increase system capacity.	Partial low-floor vehicles comply with minimum access standards for passengers with disabilities. Specialized BRT vehicles, with low floors throughout the interior allow easier access for all.
Aesthetic Enhancement • Specialized Logos and Livery • Larger Windows and Enhanced Lighting • Enhanced Interior Amenity			A distinct livery distin-guishes BRT vehicles from local buses and ties into the system branding scheme. An attractive livery can improve the image of the buses. Spacious interiors and other interior treatments improve the bus image and enhance passenger experience.	Larger windows and enhanced lighting improve visibility and enhance security.		
Passenger Circulation Enhancement • Alternative Seat Layout • Additional Door Channels • Left Side Doors • Enhanced Wheelchair Securement • Interior Bicycle Securement	Improved passenger circulation and disabled access, as well as multi-door boarding, reduce dwell time delays. Bike securement strategies can increase dwell times.	Easier disabled passenger access reduces variation in dwell time. Improved passenger circulation may reduce variation between peak and non-peak hours.	Improved access to mobility impaired groups enhances image of service. Left side doors simulate rail systems. Alternative seat layouts can also simulate rail cars.	Easier disabled securement facilitates safety.	Improved passenger circulation and multi-door boarding increases vehicle throughput of BRT facilities. Interior bike securement can reduce interior capacity.	Improved passenger circulation treatments facilitate boarding for people with disabilities. Enhanced wheelchair securement systems provide a safer, more accessible environment, while limiting delay for persons using wheelchairs and scooters.
Propulsion Systems • Internal Combustion Engines • Fuel Choice (USLD, CNG) Trolley, Dual Mode and Thermal-Electric Drives Hybrid-Electric Drive Fuel Cells	Vehicles powered by electricity (trolley, dual-mode, and hybrid-electric drives) have faster acceleration rates from stops.	Diesel buses are the most reliable technology. Early hybrids had lower reliability than diesels, but recent hybrids have good reliability.	Low emissions systems enhance the environmental image of BRT. Some propulsion systems may create noise or vibration impacts. Hybrids reduce noise.			Propulsion systems that provide a gentler ride, such as those with electric drive, increase on-board safety and comfort.

Exhibit 2-5B: Summary of Effects of Vehicle Elements on System Benefits

	System Benefits				
	Higher Ridership	Capital Cost-Effectiveness	Operating Cost-Efficiency	Transit-Supportive Land Development	Environmental Quality
Vehicle Configurations • Conventional Standard • Stylized Standard • Conventional Articulated • Stylized Articulated • Specialized BRT Vehicles • Floor Height	Stylized or specialized vehicles enhance the system brand and present a premium image, which may attract riders.	Cost increases with the complexity of the vehicle configuration. Specialized BRT vehicles cost the most. May require modifications to maintenance facilities to accommodate larger vehicles.	Smaller buses means that more buses must be used to meet capacity, increasing operating costs.	Stylized or specialized vehicles enhance the system brand and present a premium image, which may attract developers.	Larger vehicles may have greater noise impacts.
Aesthetic Enhancement • Specialized Logos and Livery • Larger Windows and Enhanced Lighting • Enhanced Interior Amenity	Attractive vehicles may attract riders and may positively influence rider perception of system performance. Distinctive logos and livery raise vehicle profile in public and make it easier to use the system.	Distinctive logos and livery require only a modest investment.	Distinct liveries results in a dedicated BRT fleet, which affects spare ratios and impacts operating strategies. Potential increase in cost of replacing and maintaining large windows. Enhanced interior materials may be more subject to wear or vandalism.	Aesthetic enhancements may improve community and developer perception of service, which could attract developer interest.	
Passenger Circulation Enhancement • Alternative Seat Layout • Additional Door Channels • Left Side Doors • Enhanced Wheelchair Securement • Interior Bicycle Securement	Attractive and spacious interior can make the ride more pleasant, attracting more riders.	Left-side doors may require additional structural modifications to vehicle orders, raising procurement costs and testing requirements.	Interior securements could impede flow	Affects only service quality.	
Propulsion Systems • Internal Combustion Engines • Fuel Choice (USLD, CNG) Trolley, Dual Mode and Thermal-Electric Drives Hybrid-Electric Drive Fuel Cells	Clean propulsion systems make the bus seem more pleasant to riders and potential customers. Electric drive buses (hybrid, trolley, fuel cell) offer a quieter and smoother ride. Clean propulsion promotes a "green image," which may attract riders.	Hybrid-electric buses are more expensive than ICE or CNG, although prices are coming down; dual-mode buses potentially have even higher incremental costs. Fuel cell buses are pre-commercial and have a very high capital cost.	Battery maintenance and replacement may add costs to use of hybrid buses. Use of hybrids will reduce fuel costs. More data are being made available about life-cycle maintenance costs of hybrid buses.	Bus noise and emissions could be a factor in attracting development around stations. Hybrids may reduce noise and emissions. CNG can reduce emissions impacts.	Low emissions systems maximize environmental quality. Lower noise levels of electric and hybrid vehicle improve rider experience and community perception.

Implementation Issues

Implementation Issues During Project Development

Several major issues should be considered when selecting vehicles for BRT operation.

Maintenance Requirements

Maintenance and storage facilities need to be modified or expanded to accommodate BRT vehicles, depending on the scope of BRT implementation. The cost impact can be anywhere between a few million to modify an existing facility to $25 million or more to build a new one.

- ***Facilities Modification and Site Re-Design*** *(Articulated Vehicles)*—Communities planning purchase of 60-ft articulated vehicles will need facility modifications to maintenance buildings and yards if the property is currently using 40-ft vehicles. Typical modifications include extension of inspection pits, installation of three-post axle-engaging hoists, modification or relocation of bus maintenance equipment, conversion to drive-through maintenance bays, and reconfiguration of parking and circulation layout of yards.
- ***Facilities Modification and Site Re-Design*** *(Hybrid and Gaseous Fuels)*—As noted in the NREL study on NYC Transit, the deployment of hybrid buses required the installation of battery reconditioning equipment, as well as an overhead crane for accessing the battery tubs located on the top of the bus. Similar access is usually required for servicing gas storage cylinders on top of the bus. If gaseous fueling is not extant, such a facility can have significant costs: in the case of NYC Transit, blasting and laying of new pipe for its CNG fueling facility cost in the area of $7.4 million.
- ***New Facility Location***—If significant numbers of new vehicles are needed, a new facility location must be identified to accommodate the BRT fleet.
- ***Fueling***—Fueling facilities may also need to be modified to accommodate new vehicles and possibly longer vehicles.

Availability of Desired Vehicle Configuration

As market demand studies have shown, because vehicles are a highly-visible transit system element, general managers of transit properties, as well as local political and civic leaders and community and rider groups, place a significant value on the vehicle image. U.S. suppliers have responded and, as a result, domestically-manufactured vehicles have advanced not only technologically but aesthetically.

Agencies looking at procuring specialized vehicles for their BRT service should keep in mind that selecting non-conventional configurations requires careful procurement planning and execution as well as coordination with relevant regulatory agencies.

Regulatory Compliance

New vehicle models must pass a variety of regulations to be approved for operation:

- ***Production***—The federal Buy America provision requires a certain percentage of the vehicle be produced within the United States. While there are exceptions sometimes granted through a waiver process, such waivers cannot be guaranteed.
- ***Safety***—Buses must satisfy regulations that govern safe operations of vehicles, such as the FTA Bus Testing Program and other safety regulations from the National Highway and Traffic Safety Administration (NHTSA). Some states also place their own standards on vehicle design, including standards on safety and design standards, such as maximum length for passenger vehicles. Some state motor vehicle regulations restrict vehicle length to 60 feet in length and 102 inches in width with axle loading of 16,000 pounds.
- ***Pollution Control***—The EPA and local air quality management districts govern requirements on pollutant emissions. For example, many articulated and bi-articulated large vehicles are produced only in diesel or electric drive. Some local air quality management districts also mandate emissions technologies that vehicle manufacturers currently do not incorporate into the vehicle models they produce.
- ***Disabled Access***—Many aspects of vehicles – boarding interface, interior layout, placement of fare systems, use of ITS, and wheelchair securement—must meet the requirements of ADA.

Propulsion Systems

Use of clean fuel or alternative propulsion options is increasing throughout the U.S. transit industry, and many agencies with BRT systems have selected clean fuel vehicle technologies for their BRT buses.

Several recent studies from the National Renewable Energy Laboratory (NREL)—one evaluating the experience of New York City Transit with hybrid and CNG buses, one on Ebus hybrid-electric buses and trolleys, and one evaluating King County Metro's hybrid articulated buses—provide real-world data that may provide substantive guidance for agencies considering these options.

As the emissions performance of diesel engines using ULSD improves and more communities are opting for hybrid powertrains, the expansion of gaseous fuels for transit seems to be slowing. As a result, engine manufacturers are reducing the number of natural gas engine models available in the transit marketplace.

The previously-mentioned studies provide a number of quantified statistics on various performance aspects of the buses on a comparative basis. While the service cycles in the studies are very different, the studies do highlight some significant issues regarding performance between the different drive trains, as well as data related to reliability and maintenance costs.

Implementation Issues During Operation

Maintenance Training

New vehicles may require new maintenance skills and procedures, especially if the BRT vehicle fleet is distinct from other vehicles.

Fleet Interchangeability

Due to branding and service considerations, mixing BRT and regular service vehicles to address demand changes would not be optimal. Differentiation in vehicles between fleets may limit ability to procure common components and parts.

Experience with BRT Vehicles

Exhibit 2-6 summarizes vehicle implementations for 41 BRT applications around the world. The data on the 20 U.S. BRT service implementations reveal that a distinctive vehicle is the most commonly used BRT element in the U.S., with only a few cites running standard fleet vehicles on their BRT systems. At a minimum, most systems use a unique logo and livery to differentiate the BRT from local bus service. Vehicle configurations range from conventional standard in lengths as short as 28 ft to 61-ft specialized BRT articulated vehicles. There are now more systems using at least some 60-ft articulated vehicles than those using only 40-ft buses.

The 28- to 30-ft buses are single-door vehicles but the higher-capacity 40- to 60-ft vehicles have two or three doors for use as entry and exit channels, as shown in the exhibit. The Civis, used in Las Vegas, has four doors; Cleveland and Eugene are the only U.S. systems that feature left-side boarding; both use articulated vehicles with two left-side and three right-side doors.

Choices for propulsion systems reflect both the technology available at the time of vehicle purchase and transit property policy. Previously, the internal combustion engine powered by ultra low sulfur diesel (ULSD) or compressed natural gas (CNG) was the predominant choice for reduced emissions. However, in recent years, more transit agencies have sought out and purchased diesel hybrid-electric drive trains for emissions control as well as fuel savings.

Several agencies use CNG buses in their BRT operations, but these are agencies that use CNG throughout their fleets; given CNG infrastructure costs, it seems unlikely that transit agencies would purchase CNG vehicles only for BRT operations. In contrast, several cities are deploying hybrid-electric buses only in their BRT service, most notably Cleveland, Eugene, and Albuquerque. In these cases, the propulsion choice seems designed to further differentiate the BRT from the conventional bus service.

BRT applications in the rest of the world reflect a wide range of vehicle approaches. Latin American systems tend to use stylized articulated vehicles, reflecting the emphasis on creating a high-capacity, "rail-like" transit service. Canadian systems have adopted varied approaches, with the York VIVA investing heavily in a distinctive fleet of BRT vehicles designed to enhance the system image. By contrast, Ottawa demonstrates that it is not necessary to use the vehicle as a branding element; Ottawa operates regular fleet vehicles on its dedicated transitway. Like Canada, European systems reveal a variety of approaches, but there are some unique vehicles in use in Europe, most notably Eindhoven's rail-like Phileas buses. Australia tends to favor high-capacity vehicles with a standard look and livery, while China also uses high-capacity vehicles but with a specialized BRT look. The use of alternative propulsion options is less common than in the U.S. Most of these ciites use diesel, and few use CNG.

Future Market Projects

In addition to the 20 applications noted above, there are an estimated 50 to 70 communities in the U.S. in some stage of planning one or more BRT corridors. Phase I of the FTA's *2007 Bus Rapid Transit Vehicle Demand Analysis* examined planned vehicle selections for 63 communities that provided insight into their potential vehicle procurements. The purpose of Phase I was to take a general snapshot of the burgeoning BRT sector and provide a foundation for Phase II of the Vehicle Demand Analysis, which focuses exclusively on "heavy-BRT" properties, quantifying the vehicle deliveries and elements for these systems over the next 10 years.

Some of the more interesting findings from the preliminary results of Phase I pertaining to vehicles and their deployment included the following:

- **Significant plans for exclusive rights-of-way.** More than 50 percent of the surveyed communities were planning on creating exclusive right-of-ways for their BRT systems within the next 10 years, an increase of more than 40 percent. This suggests the continuing growth in the use of higher capacity buses.
- **Greater interest in larger vehicles than smaller.** More BRT communities were interested in the larger, 60-ft vehicles than they were in ordering the smaller, 40-ft vehicles.
- **Rapid growth of biodiesel.** In the 2004 analysis, only one transit agency (out of 48 contacted) was interested in exploring the biodiesel fueling option. Currently, 10 percent of the respondents are using it, with substantial interest from others.
- **Preponderance of alternative fuel/advanced propulsion.** A total of 75 percent of the BRT communities were using or planning on implementing alternative fuels/advanced propulsion in their fleets.
- **Disparity between planned orders versus preferred orders.** Although many agencies were ordering special vehicles for BRT, most agencies would prefer not to order them, as a lack of funding and vehicle availability were holding them back.
- **High interest in stylized vehicles.** Interest is shifting from specialized vehicles to stylized articulated vehicles, since no North American manufacturers have committed to producing any specialized vehicles yet. (With an increasing emphasis on exclusive right-of-ways, deployment of longer, bi-articulated vehicles, or, as is being tested in Snohomish County, WA by Community Transit, a double-tall, two-deck bus may be on the horizon.)
- **Limited interest in automated guidance**. The interest in vehicle guidance, especially precision docking, would be high if the technology were more available.

In the end, it appears that the vehicle market has progressed significantly in terms of appearance, economy, emissions, and amenities. Due to dialogue among transit properties, suppliers, and manufacturers, the domestic bus industry can provide appropriate vehicles for the varying needs of BRT communities, now and in the future.

Exhibit 2-6: Experience with BRT Vehicles

	Albuquerque	Boston Silver Line			Chicago	Cleveland	Honolulu
	Rapid Ride	Washington Street	Waterfront: Airport	Waterfront: BMIP and City Point	Express	HealthLine	City Express Rt. A & County Express
Configuration	Articulated	Stylized articulated	Articulated	Articulated	Conventional standard	Stylized articu-lated	Articulated
Length	60'	60'	60'	60'	40'	60'	60'
Manufacturer and Model	New Flyer, 2005 and 2007	NEOPLAN USA	Neoplan	Neoplan		New Flyer	New Flyer
Floor Height	Low	AN 460 LF	Low	Low	High	Low	Low
Description of Livery / Image	Red & white paint, Rapid Ride logo	Step low	Silver	Silver		Distinctive silver livery	Standard livery
Interior Features	Molded plastic with fabric inserts	Silver band similar with T logo, similar to rail vehicle livery	Luggage racks	Aisle seating		Wide aisles and doors	
Right-Side Doors	3	Standard seats in 2+2 con-figuration	3	3		3	3
Left-Side Doors		3				2	0
Bus Capacity (Seated)	67	57	38	47		46	58
Bus Capacity (Seated and Standing)	110	79	53	65		120	130
Wheelchair Loading		Front door ramp	Ramp	Ramp	Lift		Ramp
Wheelchair Securement	belts	ICE	Tie-down	Tie-down	Strap		
Propulsion System	Hybrid-electric		Dual-mode diesel & electric traction	Dual-mode diesel & electric traction	ICE	Hybrid	Diesel / hybrid-electric
Fuel	ULSD	CNG	ULSD	ULSD	Diesel	Diesel	

Exhibit 2-6: Experience with BRT Vehicles (cont'd.)

	Eugene	Honolulu	Kansas City	Las Vegas	Los Angeles	Los Angeles	Miami
	EmX	City Express! Rt. B	MAX	MAX	Orange Line	Metro Rapid	South Dade Busway
Configuration	Stylized articulated	Standard	Stylized standard	Stylized articulated	Stylized articulated	Stylized standard and articulated	Conventional standard and minis
Length	60'	40'	40'	60'	60'	40' / 45' / 60'	
Manufacturer and Model	New Flyer		Gillig	Irisbus CIVIS 2003	NABI 60' BRT-01, 2005	NABI and New Flyer	30' Optares 40 NABI 40 LFW
Floor Height	Low	High	Low	Van Hool A330	Low (15")	Low (15")	Step low
Description of Livery / Image	Distinctive green livery	Standard livery	Max logo, unique livery and image, large continuous windows, sleek look	Low	Silver metallic two-tone paint scheme & Metro Orange Line branding	Red/silver two-tone paint scheme; Metro Rapid name branding	1
Interior Features	Wide aisles and doors		Modern-looking interior, increased aisle width, increase hip-to-knee room, wider doors & windows	Sleek, modern lines with large windows,	USSC Aries cloth seats		2
Right-Side Doors	3		2	Modern auto-like interior, finished window glazing	3	2 / 3	28
Left-Side Doors	2	2	0	4	0	0	52
Bus Capacity (Seated)		0		0	57	40 to 57	ICE
Bus Capacity (Seated and Standing)		45	40		69	48 to 69	Diesel
Wheelchair Loading		68		120	Ramp (at front door only)	Ramp (at front door only)	
Wheelchair Securement		lift		ramp	Telescoping ARM	Telescoping ARM	Ramps
Propulsion System	Hybrid		ICE		Cummins Westport L-Gas	ICE	Strap
Fuel	Diesel	Diesel	ULSD	Diesel electric hybrid	CNG	CNG	

Exhibit 2-6: Experience with BRT Vehicles (cont'd.)

	Oakland	Orlando	Phoenix	Pittsburgh	Sacramento	San Jose	Halifax	Ottawa
	Rapid	LYMMO	RAPID	Busways	EBus - Stockton	Rapid 522	MetroLink	Transitway
Configuration	Stylized standard		Stylized standard	Conventional standard and articulated	Standard	Stylized standard and articulated	Stylized standard	Standard and articulated
Length	40.5'	35'			40'	40' / 60'	40'	40' & 60'
Manufacturer and Model	Van Hool A330	New Flyer	NABI 40LFW		Orion VII 2004	Gillig 2001 (40'), New Flyer 2002 (60')	New Flyer, 2005	New Flyer Invero & D60LF
Floor Height	Low floor	Low	Step Low Floor	High	Low-floor	Low floor (15")	Low floor	14.5 - 16"; 11.5" kneeling
Description of Livery / Image	Red, white and green livery	LYMMO logo	Silver field with green and violet RAPID logo		Standard branded	Full bus wraps	Blue, yellow, white patterned livery and unique branding	Maple leaf livery; similar to rest of fleet
Interior Features		Padded seats, Transit TV	High-back seating, luggage racks, overhead lighting, reclining seats	Cushioned seats	Standard	Typical transit bus - front facing, upholstered seats	Cloth seats, reclining with arm and foot rests	Cloth seats
Right-Side Doors	3				2	2 / 3	2	2 / 3
Left-Side Doors								
Bus Capacity (Seated)	28	20	41		34	38 / 57	40	44 / 64
Bus Capacity (Seated and Standing)	77	36	63		55	62 / 98	60	90 / 120
Wheelchair Loading	Ramp	Ramp	Ramp	Lift	Kneeling, low-floor, ramp	Low-floor 15"	Low-floor buses, kneeling buses, ramps	Low floor buses, kneeling buses, ramps
Wheelchair Securement	Rear-facing position	Strap	Strap	Strap	Farward facing	Forward-facing 4-point restraint	Belt	Belt
Propulsion System	ICE	ICE	ICE	ICE		ICE	ICE	ICE
Fuel	ULSD	CNG	LNG	Diesel, CNG	CNG	Low-sulfur diesel	Biodiesel	Diesel

Exhibit 2-6: Experience with BRT Vehicles (cont'd.)

	York	Bogotá	Guayaquil	Pereira	Amsterdam	Caen	Edinburgh
	VIVA (All Routes)	Transmilenio	Metrovia	Megabus	Zuidtangent	Tram on Wheels	Fastlink
Configuration	Standard and articulated	Stylized articulated	Stylized standard and articulated	Stylized Articulated	Articulated	Bi-articulated	Standard single and double deck
Length	40', 60'	18 m		18 m	18m	24.5m	11.4m(double deck), 12m single deck
Manufacturer and Model	Van Hool A330 & AG300	Volvo, Mercedes, Scania, various models, various years			Van Hool	Bombardier GLT 'tram-on-tires'	Volvo B7RLE single deck, Dennis Trident Double Deck
Floor Height	Low	0.9 m		0.9 m	Low	Low	Low
Description of Livery / Image	Metallic blue with VIVA logo	Red, branded articulated buses	Blue, branded articulated buses	Green, branded articulated buses	Zuidtangent logo, red braded buses	Blue & white-twisto	Standard
Interior Features	Cloth seats in spacious arrangement, tables at some rear seats, large windows	Molded plastic seats, front/rear and side facing		Molded plastic seats, front/rear and side facing		"Bistro" style semi-circle seating at rear	
Right-Side Doors	2 / 3	1			2	3	2
Left-Side Doors		4					
Bus Capacity (Seated)	36 / 54					154	69 or 42
Bus Capacity (Seated and Standing)	50 / 72	160			130	195	88 or 70
Wheelchair Loading	Low floor buses, kneeling buses, ramps	Level boarding	Level boarding	Level boarding		Tilting low floor	Kneeling, low floor & ramp
Wheelchair Securement	Belt						Rear facing
Propulsion System	ICE	ICE		ICE			
Fuel	Diesel	Diesel, CNG pilot project underway with 3 buses		Diesel	Diesel	Dual mode-traction motor on-rail/ diesel engine off-rail	Diesel

Exhibit 2-6: Experience with BRT Vehicles (cont'd.)

	Eindhoven	Leeds	London	Rouen	Utrecht	Adelaide	Brisbane
	Phileas -Western Corridor	Superbus	Crawley	TEOR	Busway	North East Busway	South East and Inner Northern Busways
Configuration	Articulated, bi-Articulated	Standard	Standard	Articulated	Bi-articulated	Standard articulated, standard rigid	Standard rigid
Length	18m 24m (1 only)		11 m	17.9m 18m	25m	Merc Rigid 37.1' Merc Artic 57.4' Scania Rigid 38.7'	40.8'
Manufacturer and Model	Phileas- APTS	Scania l113 Single Deck, Volvo B7TL Double Decker, Scania L94UB Single Deck	Scania/ Volvo	Agora	Van Hool AGG 330	Mercedes Artic 60, Mercedes Rigid 40, Scania Rigid 40	MAN 18.310 - Volgren/ Scania L94UB - Volgren
Floor Height	Low	Low	Low	Low	Low	Merc - step high, Scania - step low	Mainly step low; some step high
Description of Livery / Image	Phileas bus logo	Standard	Fastway logo, blue/grey brand	TEOR Logo	Standard	Standard	Standard
Interior Features						Luggage racks over wheel hubs	
Right-Side Doors	3	1	2	4	4	0	0
Left-Side Doors						Artic 3; Rigid 2	2
Bus Capacity (Seated)	30 (single-artic), 38 (bi-artic)		36	43 or 40	90	Artic 65 Rigid 40/43	44
Bus Capacity (Seated and Standing)	121 (single-artic) 159 (bi-artic)		67	110 or 115	148	Artic 95 Rigid 75	62
Wheelchair Loading	Level boarding	Kneeling, low floor	Kneeling, low floor	Level boarding	Level boarding	Front door ramp	Front door ramp
Wheelchair Securement			1 wheelchair capacity			Rear facing, no straps	Rear facing, no straps
Propulsion System							
Fuel	Hybrid (LPG/electric)	Diesel	Diesel	Diesel	Diesel	Diesel	Mix of diesel, CNG

Exhibit 2-6: Experience with BRT Vehicles (cont'd.)

	Sydney			Beijing	Hangzhou	Kunming
	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1	Line B1	Busway Network
Configuration	Standard rigid	Standard rigid	Standard rigid	Articulated	Articulated	Standard
Length	41'	41'	41'	18 m	18 m	9 - 12 m
Manufacturer and Model	Volvo B12BLE Rigid	Mercedes/Scania	Scania	IVECO	Neoplan	IVECO
Floor Height	Step low	Step high	Step mixed low and step high	Low	Low	High
Description of Livery / Image	Standard	White, red stripe	Yellow	Specialized BRT vehicles	Specialized red BRT vehicles	
Interior Features						
Right-Side Doors	0	0	0	0	3	2
Left-Side Doors	2	2	2	3	0	0
Bus Capacity (Seated)	44	51	49			
Bus Capacity (Seated and Standing)	62	90	74		160	
Wheelchair Loading	Front door, low floor ramp	Mix, with a few low floor ramps	Mix, with a few low floor ramps	Low-floor, level platforms		
Wheelchair Securement	Rear facing, no straps	Rear facing, no straps	Rear facing, no straps			
Propulsion System						
Fuel	Euro 3 diesel	Diesel	Diesel			Diesel

FARE COLLECTION

Description

Role of Fare Collection in BRT

Fare collection directly affects ridership and revenue. It also plays a key role in customer service, marketing, planning and operations. With BRT, one of the more important fare collection objectives is to expedite efficient boarding, i.e., to minimize dwell times, for what are often extremely busy services. Key fare system design factors include the type of fare structure (e.g., flat fare versus zone- or distance-based pricing), the type of fare collection (e.g., pay on-board vs. off-board, proof-of-payment), and the types of payment technologies and fare media (e.g., paper vs. electronic media). This section focuses on the specific fare collection processes, structures, and technologies that might be considered for BRT systems. It describes the various fare collection options for BRT systems and provides order of magnitude cost estimates for the different types of options. (More information on fare collection systems can be found in the following Transit Cooperative Research Program publications: "Fare Policies, Structures, and Technologies Update," TCRP Report 94, 2003; "A Toolkit for Self-Service, Barrier-Free Fare Collection," TCRP Report 80, 2002; "Multipurpose Transit Payment Media," TCRP Report 32, 1998; "Bus Transit Fare Collection Practices," TCRP Synthesis of Transit Practice 26, 1997.)

Characteristics of Fare Collection

The three primary design characteristics of any fare collection system are the fare collection process, fare media and payment options, and fare structure.

- ***Fare Collection Process***—The fare collection process defines how the fare is physically paid, processed, and verified. It 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 payment options). The basic types of fare collection are driver validation (i.e., pay on-board), conductor validation, barrier-enforced payment, and barrier-free payment (or proof-of-payment).
- ***Fare Media and Payment Options***—The fare media and payment options are the means by which the fare is actually paid (e.g., cash, tokens, paper tickets/flash passes, and electronic passes/farecards). The particular media/options reflect the nature of the fare structure and collection process, as well as the technologies used (i.e., paper, magnetics, and/or smart cards). The choice and design of fare media can influence the service times, evasion and enforcement procedures, and the potential for multiple applications/partnerships, as well as the capital and operating costs of the fare collection system.
- ***Fare Structure***—The fare structure includes the basic pricing strategy (e.g., flat fare vs. fare differentiation), the transfer policy, and the actual pricing levels. As such, it influences the choice of fare collection process as well as the type of fare media/payment options; however, the fare structure can also be influenced by the payment technologies selected for BRT and by the existing fare structure of the overall transit system (or possibly the entire region). Fare structures are established based on customer, financial, operational, and possibly political considerations. The two basic types of fare structure are flat fare and differentiated fares (i.e., reflecting distance traveled, time of day of travel, or quality of service).

Fare Collection Options

Fare Collection Process

Two basic categories of fare collection processes are on-board payment systems and off-vehicle payment systems. The on-board category includes the driver-validated system and the conductor-validated system. The off-vehicle category includes both barrier systems and barrier-free systems. Deciding on an on-board or off-vehicle fare collection process is key for the BRT system and it must be done early in the planning stages, as it will affect other design and operational elements of the system. Issues associated with this decision are discussed in the Implementation Issues section. The basic types of fare collection and verification options are described below, including their relative motivations and implications. (Unit cost ranges presented in this section are based on a combination of information from transit agencies that have recently procured fare collection systems and order-of-magnitude estimates provided by various fare equipment vendors. It must be kept in mind that the actual cost associated with implementation of a particular option depends on the specific functionalities/specifications, quantity purchased, and specific manufacturer.)

Fare Collecton Options

On-Board, Driver-Validated System

This approach represents systems where fare payment and validation generally occur on-board, and the process is overseen by the driver. It typically involves a farebox and/or a standalone processing unit for tickets or cards adjacent to the operator.

COST: Exhibit 2-7 gives capital and operating costs for various fare collection options. Exhibit 2-7 table shows upper and lower estimates of capital costs (per unit) for key fare collection system elements related to driver validated systems. Operating costs are presented in Exhibit 2-7 as percentage of capital expenditures. These ranges are useful for developing order-of-magnitude estimates of the total cost of a fare collection system; the actual costs will depend heavily on the specifications and functionality, quantity of equipment purchased, and specific manufacturers of the products purchased.

Onboard Fare Collection—Houston, Texas

System/Subsystem	Unit	Capital Cost Range	
		Low	High
On-Board, Driver-Validated System			
Electronic registering farebox	Farebox	$5,000	$6,000
Electronic registering farebox (with smart card reader)	Farebox	$6,000	$8,000
Validating farebox (includes magnetic card processing unit)	Farebox	$12,000	$13,000
Validating farebox (with smart card reader)	Farebox	$13,000	$14,000
Stand-alone smart card processing unit	Vehicle	$1,500	$2,000
Integrated farebox smart card module	Module	$500	$1,000
Bus operator control unit	Vehicle	$1,500	$2,000
Magnetic farecard processing unit (upgrade)	Unit	$4,000	$6,000
On-board probe equipment	Vehicle	$500	$1,500
Garage probe equipment	Garage	$2,500	$3,500

REASONS TO IMPLEMENT

- Does not require significant fare collection infrastructure outside the vehicle and is thus typically much less expensive than other approaches.
- Better control of fare evasion (compared to proof-of-payment).

CONSIDERATIONS/ REQUIREMENTS

- Requiring passengers to board through a single front door and pay the fare as they enter—May result in significant dwell times on busy BRT routes, particularly those with heavy passenger turnover.
- Labor requirements—May involve additional maintenance, revenue servicing/collection, and clerical/data support (depending on incremental number of fareboxes over existing number).

*Exhibit 2-7: Estimated Operating & maintenance Costs for Fare Collection System Elements (2006 US $)**

Cost Elements (Variable Costs)	Low	High
Spare parts (% of equipment cost)	10%	15%
Support services (% of equip. cost, for training, documentation, revenue testing & warranties)	10%	15%
Installation (% of equipment cost)	3%	10%
Nonrecurring engineering & software costs (% of equipment cost)	15%	30%
Contingency (% of equipment/operating cost)	10%	15%
Equipment maintenance costs (% of equipment cost)	5%	7%
Software licenses/system support (% of systems/software cost)	10%	20%
Revenue handling costs (% of annual cash revenue)	3%	10%
Clearinghouse (% of annual AFC revenue, for card distribution, revenue allocation, etc) (depends on nature of regional fare program, if any)	3%	6%

**Cost information from recent system procurements, vendor estimates and general industry experience.*

On-Board, Conductor-Validated System

This approach allows the passenger to either pre-pay or buy a ticket on-board from a conductor; unlike proof-of-payment, all passengers are typically checked.

COST: (for Operating & Maintenance costs, see Exhibit 2-7)

System/Subsystem	Unit	Capital Cost Range	
		Low	High
Station hardware/software	Station	$10,000	$25,000
Garage hardware/software	Garage	$10,000	$50,000
Central hardware/software	System	$75,000	$300,000

REASONS TO IMPLEMENT

- Shorter dwell time, compared to a driver-validated system.
- Likelihood of lower fare evasion, compared to a barrier-free/proof of payment system.

CONSIDERATIONS/REQUIREMENTS

- In North America, this approach tends to be used only on commuter rail systems and is rarely applied to urban modes such as BRT (or light rail) due to the relatively short distances between stops/stations and the potential for crowded vehicles.
- Higher labor requirements than other approaches (TCRP Report 80, Table 2-6):
  - Inspection personnel — 1 FTE/350 daily passengers
  - Maintenance personnel — 1 FTE/25 TVMs
  - Revenue servicing/collector — 1 FTE/25 TVMs
  - Data processing/clerical staff — 1 FTE/15,000 daily riders
  - Security staff — 1 FTE/15 stations
  - Fare media sales staff — 1 FTE/3,000 daily passengers

Off-Board Barrier System

This approach involves fare payment at a turnstile or fare-gate, or possibly payment directly to a ticket agent, in an enclosed station area or bus platform. It may involve entry control only or entry and exit control (particularly for distance-based fares).

Turnstiles—Transmilenio

Reasons to implement:

- Creates clearly-designated paid zones to process fare payment off the vehicle, removing delays associated with fare payment from the boarding process.
- Ability to better control fare evasion (compared to proof-of-payment).
- Reduced cost of fare inspectors as needed in a proof-of-payment or conductor validation system.

Considerations/requirements:

- Requires an enclosed station or platform and is therefore difficult to implement in corridors with restricted cross-section width.
- Barriers need to be designed to accommodate access by disabled passengers.
- Highest capital cost of any of these approaches, as TVMs will be needed in addition to the faregates.
- Moderate labor requirements (TCRP Report 80, Table 2-6):
  - Maintenance personnel — 1 FTE/25 TVMs or faregates
  - Revenue servicing/collector — 1 FTE/25 TVMs
  - Security staff — 1 FTE/station
  - Data processing/clerical staff — 1 FTE/15,000 daily riders
  - Fare media sales staff — 1 FTE/3,000 daily passengers

Off-Board, Barrier-Free, or Proof-of-Payment (POP) System

In this approach, the passenger is required to carry a valid (by day, time, and fare zone, if applicable) ticket or pass when on the vehicle and is subject to random inspection by roving personnel. POP typically requires ticket vending and/or validating machines.

Barrier free fare—Translink

An alternative approach that some agencies are considering for BRT is a hybrid POP/pay-on-board system. Under this hybrid approach, passengers with passes are allowed to board through the rear door of the vehicle. It decreases dwell times although it increases the risk of fare evasion compared to a completely on-board system. Some agencies are considering hybrid pay-on-board/proof-of-payment systems, in which there are a limited number of ticket vending machines (only at a few major stops/stations), and rear-door boarding is allowed for passengers who have prepaid.

COST: (for Operating & Maintenance costs, see Exhibit 2-7)

System/Subsystem	Unit	Capital Cost Range	
		Low	High
Ticket vending machine (TVM)	Unit	$25,000	$60,000
TVM upgrade—smart card processing	Unit	$5,000	$7,500
Stand-alone validator	Unit	$2,000	$5,000
Hand-held validator	Unit	$1,500	$4,000
Station hardware/software	Station	$10,000	$25,000
Garage hardware/software	Garage	$10,000	$50,000
Central hardware/software	System	$75,000	$300,000

REASONS TO IMPLEMENT

- Supports multiple door boarding and thus lower dwell times, compared to a driver validation system; for this reason, it is frequently used in light rail systems.
- Needs fewer fare inspectors, compared to conductor validation.

CONSIDERATIONS/REQUIREMENTS

- Increased risk of fare evasion.
- When considering implementing POP, a transit agency should consider how passenger loads and turnover and interior vehicle layout will affect the ability to do on-board inspection.
- High labor requirements (TCRP Report 80, Table 2-6)
  - Roving inspection personnel — 1 FTE/3,000 daily passengers
  - Maintenance personnel — 1 FTE/25 TVMs
  - Revenue servicing/collector — 1 FTE/25 TVMs
  - Data processing/clerical staff — 1 FTE/15,000 daily riders
  - Security staff — 1 FTE/15 stations
  - Fare media sales staff — 1 FTE/3,000 daily passengers

Fare Media/Payment Options

The selection of particular fare media or other payment options reflects the agency's fare structure and collection process, as well as the technologies used (i.e., paper, magnetics and/or smart cards). The type of BRT running way, and passenger demands at stations also influences the decision. The fare equipment/technology must be capable of reading and processing the selected media, and the payment options offered depends on the fare structure.

The three primary types of fare media are cash/paper, magnetic farecards, and smart cards. The latter two options are categorized as electronic fare collection (EFC). It should be noted that, while EFC offers a number of benefits to both the agency and passengers through the additional functions that it offers, implementing EFC may add (rather than reduce) existing fare collection costs.

There are emerging alternatives for fare payment that generally involve media of broader use, not exclusively utilized for fare payment. The two primary emerging options—payment with commercial credit/debit cards and payment with mobile phones—are still under development and have not yet been widely implemented.

Cash, Tokens, and Paper Media

Traditional fare media include the use of cash (coins and bills), tokens, and/or paper fare (tickets, transfer, and flash passes). These manual fare collection media are widely applied in transit systems since they are the simplest fare equipment.

COST: (for Operating & Maintenance costs, see Exhibit 2-7)

System/Subsystem	Unit	Capital Cost Range	
		Low	**High**
Simple mechanical farebox	Unit	$2,000	$2,000
Complex electronic registering farebox	Unit	$6,000	$6,000
Paper media	Ticket/Pass	$0.01	$0.04

REASONS TO IMPLEMENT

- No need for electronic processing of fare media.
- Paper tickets or flash passes offer faster fare validation compared to electronic media.

CONSIDERATIONS/REQUIREMENTS

- Requires fare equipment on vehicles. Involves BRT vehicle operators in the fare collection and verification process.
- Boarding times (in driver validation systems) can be slower where exact change is required.
- Flash passes or tickets require visual inspection by drivers, but are typically processed faster than cash.
- Collection of data on ridership requires driver input, possibly affecting labor contracts.

Magnetic Stripe Farecards

Magnetic stripe cards are made of heavy paper or plastic and have an imprinted magnetic stripe that stores information about its value or use. This type of fare media involves the use of electronic readers, which either determine validity of a pass or deduct the proper fare from stored value (or stored rides) on a farecard when a card is swiped. Magnetic technology can be either read-only or read-write (i.e., for stored value/ride); read-write units can also facilitate the on-board issuance of magnetic farecards (e.g., transfers or day passes).

Metrocard (magnetic strip)—MTA

COST: (for Operating & Maintenance costs, see Exhibit 2-7)

System/Subsystem	Unit	Capital Cost Range	
		Low	**High**
Magnetic stripe farecards			
Validating farebox with magnetic card processing	Farebox	$12,000	$13,000
Magnetic stripe card	Card	$0.01	$0.30
Station hardware/software	Station	$10,000	$25,000
Garage hardware/software	Garage	$10,000	$50,000
Central hardware/software	System	$75,000	$300,000

Reasons to implement:

- Media are typically low cost (ranging from $0.02 to $0.30 for base material and printing requirements).
- May be compatible with existing payment media within a region.

Considerations/requirements:

- Dwell times will be longer with magnetic media than with smart cards.
- Higher equipment maintenance costs than with smart card-processing equipment.
- Requires supporting electronic fare collection infrastructure including sales network.

Smart Cards

Smart card—WMATA

Smart cards carry computer chips that can support the same payment options as magnetic stripe media. They are read by contact (placing a card next to a reader) or in a contactless manner passing a card within a certain distance of a reader. They can be used for multiple applications (e.g., transit payment and one or more other functions such as parking or toll payment, or possibly non-transportation applications such as retail purchases or university campus functions). Smart cards also facilitate fare integration among multiple transit systems in a region.

Contactless smart cards (also sometimes called "proximity cards"), in particular, have begun to receive considerable attention by transit agencies around the world as a viable fare medium.

COST: (for Operating & Maintenance costs, see Exhibit 2-7)

System/Subsystem	Unit	Capital Cost Range	
		Low	High
Smart Cards			
Validating farebox with smart card reader	Farebox	$13,000	$14,000
Smart card (plastic)	Card	$1.50	$4.00
Smart card (paper)	Card	$0.30	$0.75
Station hardware/software	Station	$10,000	$25,000
Garage hardware/software	Garage	$10,000	$50,000
Central hardware/software	System	$75,000	$300,000

While the cost of the cards is much higher than the cost of magnetic stripe farecards, it is declining. The actual unit cost will depend on the manufacturer, capabilities and quantity of the cards ordered. Also, a smart card can last 3 to 5 years, making that option economical (over the long run) compared to its magnetic counterpart, which usually lasts no more than a few months before requiring replacement. Also, a new, lower-cost type of smart card is coming into the marketplace, produced in paper. These paper cards have a useful life comparable to a paper magnetic card, and may cost as little as $0.30 apiece, depending on quantities ordered.

REASONS TO IMPLEMENT

- Faster processing times (for contactless smart cards) than magnetic stripe cards; thus, the potential for faster boarding times in a driver validation system.
- Lower maintenance and higher reliability because contactless smart card readers have no moving parts or slots into which foreign objects can be jammed.
- The smart card devices tend to be compact, providing considerable installation flexibility.
- Ease of use leads to higher rates of use and adoption by passengers.
- Can be used for multiple applications - transit payments and other uses.

CONSIDERATIONS/ REQUIREMENTS

- Requires an EFC infrastructure including sales network.
- In a POP system, requires inspectors with handheld electronic card readers to check for valid payment.
- Higher up-front cost of the cards themselves, compared to magnetic stripe farecards.

Emerging Options

Contactless fare payment typically involves cards issued by the transit agency. However, at least two other options for fare payment an agency might consider are emerging: commercial credit/debit cards and mobile personal communication devices.

Commercial Credit/Debit Cards—Commercial credit/debit cards containing contactless chips have been introduced by banks for use in retail and other payments. Transit agencies are beginning to test the use of these cards for payment of fares, and this could emerge as a viable option, to supplement, or perhaps to eventually replace some or all, agency-issued fare media.

Mobile Personal Communication Devices—Another emerging option is the use of mobile phones or similar devices for fare payment. This can involve downloading a fare instrument directly to a mobile phone and then using the phone to pay the fare, either by touching the phone to a contactless card reader (essentially using it as a form of smart card) or using the phone's screen to display proof of payment to a fare inspector or bus operator.

REASONS TO IMPLEMENT

- Deeper penetration into the broader consumer market.
- More user-friendly, as one device can be used for multiple applications.
- More marketing opportunities.

CONSIDERATIONS/REQUIREMENTS

- Required coordination with other institutions, including private and non-transportation related organizations

Fare Structure

The fare structure influences the choice of fare collection process as well as the type of fare media/payment options. Fare structures are based on an agency's customer, financial, operational and political goals. Two basic types of fare structures are flat fares and differentiated fares.

Fare Structure

	REASONS TO IMPLEMENT	CONSIDERATIONS/REQUIREMENTS
Flat Fares In a flat fare structure, the fare is the same regardless of distance traveled, time of day, or quality of service.	• Simplifies fare payment, reducing potential confusion on the part of passengers and potential disputes with operators, potentially speeding up boarding. • Simplifies enforcement, especially in a POP system.	• Fare does not reflect the higher operating costs associated with serving longer trips, providing peak service, and operating "premium" (i.e., rail, express bus and BRT) service. • Typically, has lower revenue-generating potential than a differentiated fare structure.
Differentiated Fares With a differentiated fare structure, fares vary, depending in one or more of the following ways: • ***Distance-based or zonal fares***—fare is charged as a direct or indirect function of the distance traveled. Bus operators may collect the fare when passengers board or, more rarely, as they exit the vehicle. • ***Time-of-day-based fares***—fare differs depending on the time of day or day of week (e.g., lower fares during off-peak hours or on weekends). • ***Service-based fares***—fare depends on the type or quality of service (e.g., a higher fare is charged for express bus, rail, or BRT service than for regular bus service). • ***Free (or reduced) fare area or service***—free or reduced fares are charged in a designated location (e.g., a downtown free-fare zone) or on a special service (e.g., a downtown circulator service).	• Greater potential to match fare paid to service consumed; higher operating costs associated with certain types of service (longer trips, peak service, and "premium" (rail, express bus and BRT) service are reflected in a higher fare. • Differentiated fares have a higher revenue-generating potential than do flat fares.	• Adds complexity to the system, making it more difficult for riders to understand and use it. • May lead to inequitable fares, such as zonal systems or riders making very short trips but crossing a zone boundary. • Requires enforcement.

Effects of Fare Collection Elements on System Performance and Benefits

Exhibit 2-8 summarizes the links between the fare collection process, fare media/payment options and fare structure and the BRT system performance indicators and system benefits identified in Chapter 1. These links are explored further in Chapters 3 and 4.

Exhibit 2-8: Summary of Effects of Fare Collection Elements on System Performance

	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Fare Collection Process On-Board • Driver-Validated • Conductor-Validated Off-Board • Barrier Proof-of-Payment	Off-board payment enables all-door boarding, reducing vehicle dwell time and, thus, overall travel time. On-board conductor-validated fare payment allows faster boarding than driver-based on-board payment.	Off-board payment enables all-door boarding, reducing delays due to irregular dwell time and thus improving reliability.	Off-board payment, especially barrier-enforced fare collection, may convey image of a higher quality service and appear more rail-like.	Bus operators provide presence on all vehicles. Fare inspectors provide additional presence on vehicles and at stops/stations. POP may create additional security needs.	Travel time savings and improved reliability from all-door boarding improve system throughput.	Off-vehicle payment increases on-board space to maneuver with mobility aids.
Fare Media/Payment Options • Cash, Tokens & Paper • Magnetic Stripe Farecards • Smart Cards • Emerging Options (Credit/Debit Cards and Mobile Communication Devices)	Contactless smart cards (or flash passes) permit faster processing times than cash and magnetic stripe cards and thus the potential to reduce boarding times. Smart cards and farecards that can be used for other modes can reduce ease the transfer process.	Contactless smart cards (or flash passes) permit faster processing times than cash and magnetic stripe cards and thus increase potential for reducing dwell time delays especially during peak hours.	Electronic fare collection (magnetic strip and smart cards) and emerging options (credit/debit cards) and mobile phones) enhance convenience, can take advantage of multiple applications, and may convey image of a higher quality service. Electronic fare collection that can also be used for rail modes reinforces a sense of an integrated rapid transit network.		Travel time savings and improved reliability from use of contactless smart cards improves system throughput.	
Fare Structure • Flat • Differentiated	Differentiated fares are more complicated and may slow down boarding, increasing dwell time and overall travel time.	Differentiated fares are more complicated and may slow down boarding, increasing dwell time and reducing reliability.	Premium fares may convey image of a higher level of service.			

Exhibit 2-9: Summary of Effects of Fare Collection Elements on System Benefits

	Higher Ridership	Capital Cost-Effectiveness	Operating Cost Efficiency	Transit Supportive Land Development	Environmental Quality
Fare Collection Process On-Board • Driver-Validated • Conductor-Validated Off-Board • Barrier Proof-of-Payment	Shorter travel times and improved reliability from off-board or conductor-validated fare collection can help attract and retain riders.	Barrier systems have the highest capital costs.	If reduction in dwell time is large enough, it may allow shorter headways (i.e., better service without adding vehicles)	Bus operators provide presence on all vehicles. Fare inspectors provide additional presence on vehicles and at stops/stations.	Travel time savings and improved reliability from all-door boarding improve system throughput.
Fare Media/Payment Options • Cash, Tokens & Paper • Magnetic Stripe Farecards • Smart Cards • Emerging Options (Credit/Debit Cards and Mobile Communication Devices)	Increased convenience and user-friendliness of electronic fare collection (magnetic stripe and smart cards) can help attract and retain riders.	Use of contactless smart cards and emerging options offers potential for lower fare equipment maintenance costs than cash processing or magnetic strip systems.	Use of electronic media in general results in lower cash-handling costs.	Affects service quality only.	Electronic fare collection can reduce dwell time, which lowers emissions.
Fare Structure • Flat • Differentiated	Flat fares tend to result in higher ridership. Peak/off-peak differential can encourage greater off-peak usage.	Differentiated fares tend to result in higher revenue.			

Implementation Issues

Issues During Project Development

Fare collection-related issues that an agency should consider during project development (e.g., during planning, design and procurement) include the following:

General Planning/Design Considerations

In addition to an evaluation of the relative system performance impacts and benefits associated with the different options, the choice of a BRT fare collection process, fare structure, payment options, and media technology typically incorporate the following considerations:

- ***Station/Stop Design and Infrastructure Requirements***—With off-board fare collection, stations need to be designed to accommodate required fare collection equipment—for instance, space for one or more TVMs, electric supply, and data/communications connections.
- ***System Costs and Available Funds***—The choice of a fare collection system will ultimately depend on its cost and funds available for this element. As explained earlier, a POP system will typically have a higher cost—for both capital and operations—than a driver validation system.
- ***Integration with Agency-Wide Fare Policy and Technology***—The choice of fare structure, payment options, and media technology should be tied, to the extent possible, to the operating agency's existing policies and legacy systems. The fare collection system for BRT should be designed to facilitate seamless integration with the agency's other modes/services, and with other agencies in the region to the extent possible.

Fare Media Technology Standards

Many current and new transit systems (including BRT implementations) are migrating to or implementing electronic fare collection systems especially with smart cards. Promoting standardization and interoperability among different smart card technologies, therefore, has become a key concern in the transit industry. Agencies want to facilitate the availability of multiple sources of cards as they introduce smart card systems. Moreover, in regional systems, the integration of fare payment among multiple agencies requires each of the participants to be able to accept cards issued by the other participating agencies. Thus, it is essential that all participating agencies agree either to procure the same system (i.e., from a single vendor) or on a common technology standard that ensures interoperability if agencies select systems from different vendors.

Several smart card standardization efforts have been initiated in recent years. A dual contactless card "standard" (called "Type A" and "Type B") has been established by the ISO 14443 standards development group. This standard covers several aspects of the card design and card-reader interface. However, sharing a common interface does not guarantee interoperability; software communications must also be compatible, and there must be shared security data. At the software communications level, different suppliers are rarely compatible. Thus, unless they plan to rely on a single vendor, it is important that agencies participating in an integrated payment program agree on a common set of specifications for all smart card system components.

Several efforts are under way to establish industry-wide, international, or regional system standards for transit smart card applications, such as:

- ***CALYPSO***—Developed by a group of transit providers in Europe, CALYPSO is a smart card system standard that can be licensed by any interested agency. Eleven vendors are currently licensed to produce CALYPSO-compatible cards and readers. (Transit agencies in Paris, Venice, Lisbon, Brussels and Constance [Germany] developed CALYPSO between 1998 and 2000.)
- ***ITSO and EU-IFM***—The Integrated Transport Smartcard Organization (ITSO) is a public-private partnership of transit operators and government agencies in the United Kingdom that has developed a specification for the provision of "interoperable contactless smart card transport ticketing and related services in the UK" (ITSO 2006). Through a partnership with other European organizations, ITSO is now trying to establish compatible smart card-based ticketing systems within the EU member nations.
- ***UTFS—APTA and FTA*** are sponsoring the Universal Transit Fare System (UTFS) Standards Program, aimed at developing an industry standard and set of guidelines that U.S. transit agencies can use in developing electronic payment systems. As of 2007, a Contactless Fare Media System Standard had been developed (APTA 2007).
- ***New York Regional Smart Card Interface Specification***—The Port Authority of New York and New Jersey, in conjunction with other agencies in the New York City/Northern New Jersey region, has developed an "Inter-

face Specification" designed to facilitate interoperability among payment systems implemented in the coming years by the region's transit providers.

Interface Requirements/Opportunities with Other BRT Technologies and Infrastructure

BRT fare equipment can stand alone or interface with other equipment/technologies. For instance, on-vehicle equipment (i.e., farebox or stand-alone smart card readers) can interface with an automated vehicle locator (AVL) system to record the location (i.e., stop or station) of each transaction (in addition to time and bus run data). An interface is also possible with automatic passenger counting (APC) systems. The bus operator control unit (OCU) used in conjunction with the farebox can also serve multiple functions; in addition to providing operator display and controls for the fare collection device(s), the OCU can be programmed to allow operator control of a stop announcement system. In general, a farebox/smart card reader can upload and download data via an existing "smart bus" data communications system, rather than through use of an independent fare collection communications system. To take advantage of such interface possibilities, each component intended for integration must meet a common data interface standard (e.g., SAE J1708 and J1587, or the newer J1939).

Fare Collection Infrastructure

An important aspect of providing electronic fare media is offering convenient purchase/revalue options to passengers. Key options that should be considered include the following:

- ✧ Credit/debit/ATM cards can be used in many TVMs to purchase or revalue fare media. In addition, the use of contactless credit cards is now being tested as a means of direct fare payment.
- ✧ Transit vouchers are provided by many employers (typically as part of a transit benefits program) to allow employees to purchase fare media from any of the transit agencies in a region.
- ✧ Transit agencies have begun to offer account-based or autoload arrangements for passengers with smart cards. A passenger (or his/her employer) establishes a transit account with the agency; the account is typically backed by a credit card. The passenger's card is automatically loaded (with a predetermined amount of stored value or the next month's pass) when presented to a card reader (i.e., at a TVM or farebox).
- ✧ Re-usable fare media can be initially purchased or requested by telephone, mail, or internet. The passenger can then load (or reload) value or a pass to the farecard at a TVM or through an autoload program. An emerging option is to download a fare instrument directly to a mobile phone and then use the phone to pay the fare, either by touching the phone to a contactless card reader (i.e., essentially using it as a form of smart card) or simply using the phone's screen to display proof of payment to a fare inspector or bus operator.

Issues During Operation

Fare collection-related issues an agency should consider once the BRT project development has been completed include the following.

Labor Requirements

The use of POP typically has a greater labor requirement than a driver validation system due to the need for fare inspectors. Agencies should consider the trade-off between this additional labor requirement and any savings due to improved operations and fleet utilization.

Revenue Processing

The use of EFC technologies (magnetic stripe farecards and contactless smart cards) has led to improvements in revenue processing and control, including improved data collection and operations monitoring. EFC systems should produce a reduction in both labor-intensive cash handling costs and the risks of internal theft of cash. EFC systems also permit automation of financial processes, facilitating fare integration among multiple operators. Such multi-modal and multi-agency networks result in seamless regional travel for passengers. Thus, these systems benefit both transit agencies and passengers.

Data Collection to Support Planning

The types of data directly or indirectly retrieved from fare collection systems are often used to support planning activities. Therefore, the choice of fare system options should consider the types of useful data that can be generated. For example, on-board EFC systems can potentially be linked to automated vehicle location systems to allow collection of information on boardings by location as well as time of day.

Equipment Reliability/Maintainability

The type of fare media technology affects the reliability and maintainability of the fare collection equipment. Equipment used to read contactless smart cards has no openings/slots and no moving parts, making it considerably more reliable and easier to maintain than magnetic stripe farecard equipment.

Fare Evasion and Enforcement

The type of fare collection process selected will have an impact on the potential for fare evasion and the nature of enforcement necessary. In a pay-on-boarding system, every rider passes by the operator and either deposits cash or presents/inserts some type of farecard or pass. Thus, the rate of evasion is typically quite low. However, some fare evasion is inevitable in any type of fare system even with driver-validated pay on-board systems, especially in cases with more crowding.

The potential for fare evasion is higher in a POP system, as only a portion of riders are checked for proof of payment. Enforcement in a POP system is done through random inspections by roving inspectors, and the need for inspectors will significantly increase operating costs. (Note, however, that a benefit of this approach is that fare inspectors also serve to support the security of the system.) The extent of evasion depends on a variety of factors, including the inspection rate and pattern, the fine structure, the inclination of inspectors to issue warnings vs. citations, the level of crowding in the vehicle or on the platform, and, to some extent, the complexity of the fare structure and the ease of use of the TVMs/validators.

Potential Partnerships and Multiapplication Opportunities

Smart cards, in particular, can benefit passengers, and thus agencies, by providing multiapplication opportunities that allow for the potential combination of transit payments with various other types of applications and/or payment media. Potential partnerships and multiapplication opportunities include the following (for discussions of multiapplication opportunities and examples, see TCRP Report 80):

- Electronic toll collection and parking payments
- Financial services/e-purse payments
- Payphones and mobile commerce
- Other payment and loyalty programs
- Vending machines
- Identification purposes for security and access into buildings

Marketing

Fare-system-related marketing activities include (1) education of passengers as to how to use the fare equipment and media on the BRT system (including how to purchase and revalue) and (2) promotion of use of the BRT system through pricing or payment option initiatives. Pricing incentives/special features possible with EFC—smart cards, in particular—include "negative" balance protection (allowing the passenger to board even if the card contains insufficient funds for that trip), lower fares with use of the card than if paying cash, free/reduced-price transfers only with use of the card, a frequency-based discount (e.g., ride 10 times, get a free ride), or even a "lowest fare" guarantee (once a card is used a certain number of times within a given time period, it becomes an unlimited-ride pass). Payment partnerships with entities such as employers and universities can also provide effective marketing opportunities for an agency.

Experience with BRT Fare Collection

Summary of Implementation

Most BRT systems in the United States continue to use on-board farebox payment as the primary fare collection mechanism. Three systems use off-board collection with proof-of-payment enforcement: the Las Vegas MAX, the Los Angeles Orange Line, the Cleveland HealthLine; a fourth, the Eugene EmX, currently has no fares but will implement off-board proof-of-payment when the second EmX line is built. For the Pittsburgh busways, passengers on inbound trips pay on the outbound portion of the trip in order to expedite loading and reduce dwell times in downtown Pittsburgh. Boston's Silver Line Waterfront line has three underground stations with barrier systems; the surface stops rely on farebox based payments.

Implementation of electronic fare collection is increasing in the U.S. transit industry. A majority of the U.S. BRT systems in Exhibit 2-10 have electronic fare collection. Use of ticket vending machines is less common, corresponding with the few systems that have off-board fare collection.

By contrast, off-board fare collection is common in the European, Latin American, and Chinese BRT systems and some Canadian systems. The Latin American BRTs use barrier-enforced systems, reflecting their emphasis on substantial station infrastructure that can support an enclosed boarding area. The three systems cited also employ smart cards. The European BRTs typically combine on-board payment with proof-of-payment systems; about half have implemented electronic fare collection. Interestingly, the three Australian BRTs have on-board payment even though they use off-street running ways and stations that could support off-board payment schemes.

Overall, use of zone-based fares is rare, with most BRTs charging a flat fare.

Exhibit 2-10: Experience with BRT Fare Collection

	Albuquerque	Boston – Silver Line		Chicago	Cleveland	Eugene	Honolulu
	Rapid Ride	Washington St	Waterfront (All Routes)	Neighborhood Express	Healthline	EmX	City and County
Fare Collection Process	Pay on-board	Pay on-board	Barrier at 3 underground stations; pay on-board elsewhere	Pay on-board	Proof-of-payment	Planning pay off-board	Pay on-board
Fare Media / Payment Options	Cash, paper	Cash, paper transfers, magnetic stripe, smart card	Cash, paper ticket, smart card	Cash, paper, magnetic stripe			Cash, paper, magnetic stripe
Fare Structure	Flat	Flat, with free transfers to rail	Flat	Flat		Currently free	Flat
Equipment at Stations			TVMs at 3 underground stations and 5 airport terminals				
Equipment for On-Board Validation	Electronic farebox	Electronic farebox	Electronic farebox, GPS	Electronic farebox			Electronic farebox

Exhibit 2-10: Experience with BRT Fare Collection (cont'd.)

	Kansas City	Las Vegas	Los Angeles		Miami	Oakland	Orlando
	Main Street MAX	North Las Vegas MAX	Metro Rapid	Orange Line	South Dade Bus-way	Rapid San Pablo Corridor	LYMMO
Fare Collection Process	Pay on-board	Proof-of-payment	Pay on-board	Proof-of-oayment	Pay on-board	Pay on-board	
Fare Media / Payment Options		Magnetic stripe	Cash, paper passes	Tickets, standard paper passes	Cash, paper, magnetic stripe card	Cash, paper, smart card	
Fare Structure	Flat	Flat	Flat	Flat	Flat	Flat	Free fares
Equipment at Stations		Ticket vending machines (TVMs)		Ticket vending machines (TVMs			
Equipment for On-Board Validation		Hand-held validators	Electronic farebox		Electronic farebox	Electronic farebox	

Exhibit 2-10: Experience with BRT Fare Collection (cont'd.)

	Phoenix	Pittsburgh	Sacramento	San Jose	Halifax	Ottawa	York, ON
	RAPID	All Busways	EBus	Rapid 522	MetroLink	Transitway	VIVA
Fare Collection Process	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay-on board	Proof-of-payment	Proof-of-payment
Fare Media / Payment Options	Cash, paper	Cash, paper	Cash, passes	Cash, paper passes, smart cards in de-velopment	Cash, ticket, passes	Cash, paper tickets, passes	Paper tickets, passes
Fare Structure	Differentiated	Differentiated; dis-tance-based for express services	Flat	Flat	Flat	Flat (with some differentiated fares by service level)	Differentiated (by zones)
Equipment at Stations						TVMs	TVMs
Equipment for On-Board Validation	Electronic farebox	Electronic farebox		Electronic farebox	Electronic farebox		

Exhibit 2-10: Experience with BRT Fare Collection (cont'd.)

	Bogotá	Guayaquil	Pereira	Amsterdam	Caen	Edinburgh	Eindhoven
	Transmilenio	Metrovia	Megabus	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor
Fare Collection Process	Barrier (verify at station entrances / exits)	Barrier	Barrier (verify at station entrances)	Pay on-board or proof-of-payment	Pay on-board or proof-of-payment	Pay on-board or proof-of-payment	Proof-of-payment, pay on-board machine, no driver payment
Fare Media / Payment Options	Smart cards	Cash, smart cards	Smart cards	Paper (Strippenkart)	Smart cards, magnetic tickets	Cash coin (exact change) or smart card	Paper (Strippenkart)
Fare Structure	Flat	Flat	Flat	Zone system	Flat rate	Flat daytime, night-bus fare after 12am	Zone system
Equipment at Stations	Add-value machines, Nextbus	Add-value machines, Nextbus	Add-value machines, Nextbus		TVM	Partial route TVMs	Limited TVM
Equipment for On-Board Validation	None	None	None	Validator	Validator, smartcard reader	Farebox	Electronic farebox, validator

Exhibit 2-10: Experience with BRT Fare Collection (cont'd.)

	Leeds	London	Rouen	Utrecht	Adelaide	Brisbane	Sydney
	Superbus	Crawley	TEOR	Busway	North East Bus-way	South East and Inner Northern Busways	T-Ways
Fare Collection Process	Pay on-board	Pay on-board	Off-board	Proof-of -payment, pay on-board	Pay on-board (80% pre pay multi-rider ticket)	Pay on-board	Pay on-board
Fare Media / Payment Options	Cash and paper only	Cash	Magnetic stripe	Paper (Strippenkart)	Cash, paper Magnetic stripe	Cash, paper, magnetic stripe	Cash, paper, magnetic dtripe
Fare Structure	Differentiated by distance and time of day	Flat rate	Flat rate	Zone system	Flat	4 fare zones for South East;	Zone system
Equipment at Stations			TVM (not currently in use)				
Equipment for On-Board Validation	Farebox	Farebox		Validator	Electronic farebox validators	Electronic farebox	Electronic farebox

Exhibit 2-10: Experience with BRT Fare Collection (cont'd.)

	Beijing	Hangzhou	Kunming
	Line 1	Line B1	Busway Network
Fare Collection Process	Pay attendents at station	Pay at station	Pay on-board
Fare Media / Payment Options	Cash, smart cards	Cash, smart cards	Cash, IC cards
Fare Structure	Flat	Flat	Flat
Equipment at Stations	None		None
Equipment for On-Board Validation	None	Farebox	

INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

Description

Role of Intelligent Transportation Systems in BRT

Intelligent Transportation Systems (ITS) enhance transportation system performance through the use of advanced communications technologies. They have helped transit agencies increase safety, operational efficiency, and quality of service, and have improved riders' convenience, access to reliable and timely information. ITS 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 ultimately the customer. Various technologies combine to form distinct types of ITS systems. For example, automatic vehicle location (AVL) in combination with automated scheduling and dispatch (ASD) and transit signal priority (TSP) can improve schedule adherence, resulting in better service reliability as well as faster revenue speed.

ITS technologies provide many performance enhancements and benefits. The remote monitoring of transit vehicle location and status and passenger activity improves passenger and facility safety and security. Also, ITS can be used to assist operators in maintaining vehicle fleets and notifying mechanics about impending mechanical problems as well as routine maintenance needs. In short, ITS applications are fundamental to generating many benefits for a BRT system.

Characteristics of ITS

Many ITS technologies can be utilized for BRT systems. Many have been applied to conventional bus systems. This section discusses individual ITS technologies that should be considered for integration into BRT systems. Several of these technologies have already provided significant benefits as part of BRT systems. The various ITS applications that can be integrated into BRT systems are discussed below and can be categorized into six groups:

- Transit Vehicle Prioritization
- Intelligent Vehicle Systems
- Operations Management Systems
- Passenger Information Systems
- Safety and Security Systems
- Electronic Fare Collection Systems (discussed in Fare Collection)

Note that the technologies discussed in this section do not comprise a comprehensive list of Intelligent Transportation Systems. Only those technologies with direct relevance to BRT applications are presented.

ITS Options

Transit Vehicle Priorities

Transit vehicle prioritization technologies include methods to provide preference or priority to BRT vehicles to pass through intersections or sections of roadway. The intent is to reduce the overall delay of vehicles at traffic signals (providing higher operating speeds and reduced travel time), and to achieve improved schedule/headway adherence and consistency (providing enhanced reliability and shorter waiting times). Traffic signal delay is often the most significant cause of travel time delays on urban streets. A red signal not only causes a BRT vehicle to fall behind schedule, but it also can compound schedule adherence problems if the bus was already running late before approaching a red signal. A number of methods are available to minimize the impact of traffic signal delays to transit vehicles. These include the optimization of traffic signal timing, utilization of station and lane access control, and transit signal prioritization. Signal timing/phasing and transit signal priority help minimize the delay caused by vehicles having to stop for traffic at intersections. Access control provides the BRT vehicles with unencumbered entrance to and exit from dedicated running ways and/or stations.

Transit Vehicle Priorities

Signal Timing/Phasing Optimization

Traffic signal sequences can be rearranged at selected intersections to reduce delay for BRT vehicles. Reduced cycle length, phasing changes, and offset turning for bus speeds are three techniques that can be used to reduce the delay of buses at traffic signals. Assessment of this approach requires analysis and possible operations modeling using vehicle- and person-flow data but does not require additional components for the vehicle or infrastructure.

Signal timing/phasing optimization relies on pre-defined timings and does not adapt to the real-time traffic conditions.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Signal Timing/Phasing Optimization					
Signal retiming	Intersection	$3,000	$4,000	$300	$400

REASONS TO IMPLEMENT

- Can be implemented quickly with standard traffic signal equipment.
- Protect buses from conflicting vehicle traffic.

CONSIDERATIONS/ REQUIREMENTS

- Does not consider real-time conditions of the transit operation for real-time operations management.
- May require updated signal technology for coordination.
- Institutional resistance may be encountered; complaints from public may increase.
- Should not adversely impact other road users.

Transit Signal Priority

Transit signal priority (TSP) can alter signal timing to give priority to BRT vehicles. Signal timing is changed by either extending the green for the detected vehicle, truncating an opposing movement to provide an early green, or inserting a bus movement to reduce delay to the BRT. This allows BRT vehicles to improve schedule adherence, reliability, and speed. The technology requires installation of sensors on buses and at intersections along bus routes. Available strategies include green extension (extending the green phase to allow BRT vehicles to travel through) and early green (providing an early green signal to allow BRT vehicles to spend less time at an intersection). Sometimes transit signal priority treatments may be coupled with dedicated queue bypass lanes, or a special "buses only" signal, where BRT vehicles stop on the near side shoulder to provide buses with the right-of-way for rejoining the general purpose travel lanes.

Several TSP technologies and signal priority methods are available. A basic TSP system consists of communication from a BRT vehicle to a receiver at signalized intersections. A signal is sent from the BRT vehicle to the signal at the upcoming intersection. In turn, priority may be given to that vehicle. Emitters on board buses use short range communications such as infrared and radio frequency (RF) to communicate with the receivers .

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Transit Signal Priority					
Emitters	Vehicle	$900	$1,100	$40	$50
Receivers	Intersection	$1,000	$2,000	$40	$80
Phase selector	Intersection	$1,800	$2,000	$75	$80
Software (MDT modifications)	System	$50,000	$100,000	$5,000	$10,000
Control box and controller	Intersection	$8,000	$10,000	$320	$400
Interface to AVL	System	$25,000	$25,000	$2,500	$2,500

REASONS TO IMPLEMENT

- Reduced traffic signal delay.
- Improved on-time performance.

CONSIDERATIONS/ REQUIREMENTS

- Signal control systems may need to be upgraded to accommodate different signal priority algorithms.
- Requires field equipment to be installed.
- Requires approval by and coordinating with third parties, such as cities (specifically traffic engineering departments) and other stakeholders.
- Minimize adverse impacts to CWSS street traffic.

Station and Lane Access Control

Station and lane access control systems allow access to dedicated BRT running ways and stations with dynamic message signs (DMS) and gate control systems. These systems require the installation of barrier control systems that identify a vehicle and/or similar surveillance and monitoring systems. Typically, these systems utilize an electronic transponder (similar to a transponder used for electronic toll collection systems).

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Station/Lane Access Control					
Controller software	System	$25,000	$50,000	$2,500	$5,000
Gate hardware	Entrance	$100,000	$150,000	$4,000	$6,000

REASONS TO IMPLEMENT

- Prevents unauthorized entrance to facilities.
- Reduces travel time.
- Monitors access of vehicles/personnel to facilities.

CONSIDERATIONS/ REQUIREMENTS

- Requires transponders for effective access.

Intelligent Vehicle Systems

These technologies provide automated controls—lateral (i.e., steering) and longitudinal (i.e., starting, speed control, stopping)—for BRT vehicles. Intelligent vehicle systems help to reduce frequency and severity of crashes and collisions and reduced running times and station dwell times.

Precision docking and lane-assist technologies can help reduce the lane width required to operate BRT vehicles. They can, therefore, enable the deployment of BRT systems (possibly with dedicated lanes) in environments with constrained right-of-way. These technologies can also help reduce station dwell time by consistently achieving small gaps at stations, providing level boarding.

ITS-based precision docking and lane-assist systems are still in the early stages of system development. Limited operational experience both in the U.S. and abroad has resulted in very limited information regarding system performance, system reliability, maintenance requirements, failure modes, etc. Other non ITS-based guidance systems, (i.e., mechanical guidance, such as curb-guided buses) have been deployed in several cases in Europe and Australia.

Precision docking and lane-assist systems require coordinated design with running ways and stations. The running way standpoint of these technologies is discussed under the running way section of this document.

Intelligent Vehicle Systems

Collision Warning

Collision warning systems alert BRT vehicle drivers about the presence of obstacles or the impending impact with pedestrians or obstacles. This includes forward, rear, or side impact collision warning systems or integrated 360-degree systems (a system that covers all sides of the BRT vehicle). These technologies employ the use of microwave radar to scan the environment surrounding the vehicle. Upon detecting an obstacle, the system automatically warns the BRT operator.

A similar but more advanced system being developed is called collision avoidance. This system works similar to collision warning systems but, upon detecting an obstacle, automatic systems take control and decelerate the engine or apply the brakes if a driver does not properly respond to avoid colliding with the detected obstacle. However, as of 2008, these systems were still in research or early implementation stages and are not widely available for installation on BRT vehicles.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Collision Warning					
Sensor integration	Vehicle	$3,000	$4,000	$300	$400

REASONS TO IMPLEMENT

- Reduced maintenance costs.
- Reduced vehicle out-of-service time.
- Increased passenger and driver safety.
- Potential reduced insurance costs.

CONSIDERATIONS/ REQUIREMENTS

- Requires installation of sensors (infrared, video or other) and driver notification devices on-board vehicle.

Precision Docking

Precision docking assists BRT drivers in accurately placing a vehicle at a stop or station location in terms of both longitudinal control (parallel to the station) and lateral control (side-to-side). Sensors continually determine the lateral distance to the curb, front and rear, and the longitudinal distance to the end of the bus loading area. ITS-based technologies to implement precision docking include optical, magnetic, machine vision, or microwave radar. Other non ITS-based methods include mechanical guidance, such as curb guided vehicles and single rail vehicles. These non-ITS methods are discussed in the Running Ways section of this document.

Optical guidance is the most commonly used ITS-based technology for precision docking. Both magnetic and optical options require the installation of markings on the pavement (paint or magnets), vehicle-based sensors to read the markings, and linkages with the vehicle steering system.The availability of these systems is currently limited (as of 2008) to international suppliers as an additional option for new vehicle purchases. Commercial availability from U.S. suppliers as an add-on option is likely in the next two to five years.

Precision docking with guided buses has been operational for about 10 years in Europe, using mechanical guidance technology. More recently, precision docking and level boarding have been developed using optical guidance technology and are in revenue service in France. In the U.S., optical guidance was implemented in the Las Vegas MAX system. However, the technology deployed in that system is not in use because local conditions require significant maintenance of the optical guidance markers to operate reliably.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Precision Docking					
Magnetic sensors	Station	$4,000	$4,000	$160	$160
Optical markings	Station	$4,000	$4,000	$160	$160
Hardware and integration	Vehicle	$50,000	$50,000	$5,000	$5,000

REASONS TO IMPLEMENT

- Improves passenger convenience during boarding and alighting.
- Reduces delay at stops.
- Increases passenger convenience.
- Increases passenger and driver safety.
- Reduces insurance costs.

CONSIDERATIONS/ REQUIREMENTS

- Requires vehicle-based systems as well as coordinated running way design and station design.
- Limited deployment to date.
- Infrastructure may require significant maintenance based on local conditions of the area.

Lane-Keeping Assistance Systems

Lane-keeping assistance systems (or vehicle guidance systems) guide BRT vehicles on running ways while maintaining or allowing for higher speed. This is done by providing feedback to the driver or by controlling the vehicle automatically. These technologies allow BRT vehicles to safely operate at higher speeds in dedicated or semi-dedicated lanes that may be narrower than standard traffic lanes (e.g., 10-ft wide as opposed to a standard lane width of 12 ft). Such systems are necessary to sustain safety because of the smaller margin for error associated with a narrower lane width, especially when it is adjacent to regular traffic. There are three primary ITS-based lane assist technologies: magnetic, optical, and GPS-based. (Mechanical guidance systems are described in the Running Way section of this chapter). The availability of these systems is currently limited. However, commercial deployment is expected within two to five years.

- **Optical** (or vision-based guidance systems) use machine vision equipment (cameras, image processing equipment, pattern recognition algorithms, etc.) to provide the lane-assist system with information as to the exact location of the equipped bus within the lane.
- **Magnetic** guidance systems use magnetic material (i.e., magnetic tape, magnetic plugs) either located on or embedded in the roadway to provide a reference magnetic field. Sensors installed on the bus, consisting of multiple magnetometers, compare the relative field strength measured by each magnetometer. From those measurements, the lateral distance to the magnetic reference is determined.
- **GPS-based** guidance utilizes GPS to provide position information. However, to determine bus position relative to the lane, the location of lane boundaries must also be known. A digital map containing the location of all relevant road elements is used. The database is queried based on vehicle location, and the query results provide the location of the lane boundaries and other objects. From that information, the position of the vehicle with respect to the lane can then be determined and used by the lane assist system.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Lane-Keeping Assistance System					
Magnetic sensors	Mile	$20,000	$20,000	$800	$800
Optical	Mile	$20,000	$20,000	$800	$800
Hardware (including GPS) and integration	Vehicle	$50,000	$95,000	$5,000	$9,500

REASONS TO IMPLEMENT

- Reduces vehicle maintenance costs.
- Reduces vehicle out-of-service time.
- Increases passenger and driver safety.

CONSIDERATIONS/ REQUIREMENTS

- Requires vehicle-based systems as well as coordinated running way design and station design.
- Infrastructure may require significant maintenance due to local conditions of the area.
- GPS-based systems require very accurate maps that include road network, facilities and stations, which may not be available or are available at a high cost.
- Not widely available.

Operations Management Systems

This group of technologies includes systems that enhance BRT operations by improving operating efficiencies, increasing service reliability and reducing travel times. These technologies include transit operations software applications that assist transit agencies with driver scheduling, vehicle assignment and dispatching. Increasingly, these software products are being integrated with each other for additional benefits. For example, computer-aided dispatching (CAD) combined with AVL is the most popular form of transit operations technology. CAD/AVL gives transit agencies the capability to monitor, supervise, and control operations with real-time data and provide real-time information to customers.

Operations Management Systems

Computer-Aided Dispatch (CAD)

A CAD system can manage a voice and data communication system by automatically selecting appropriate channels for specific types of communications; allowing operations/dispatch to select a specific vehicle, group of vehicles, or all vehicles to receive messages; and facilitating emergency response in the case of an incident. Currently, CAD systems are very prevalent in fixed-route bus operations.

Usually, CAD systems also include the installation of mobile data terminals (MDT) in each vehicle near the operator. The MDTs facilitate data transfer between the vehicle and operations/dispatch. The use of MDTs for data communication tends to reduce the volume of voice communication since much of the information transmitted between operators and dispatch can be coded.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
CAD System					
Software	System	$100,000	$150,000	$10,000	$15,000
Hardware	System	$10,000	$20,000	$400	$800
MDTs	Vehicle	$3,800	$6,500	$160	$250
Interface to AVL	System	$20,000	$50,000	$2,000	$5,000

REASONS TO IMPLEMENT

- To promote improved efficiency and productivity of the operation by reducing unnecessary communication between dispatches and drivers, improving the collection and archiving of operations events, and providing new information and analysis tools to assist operations decision-making.

CONSIDERATIONS/ REQUIREMENTS

- Requires a data communication system to be installed.

Automatic Vehicle Location (AVL)

An AVL system determines the location of each vehicle that is equipped with the required hardware and software. The most popular technology currently used to determine location in an AVL system is the global positioning system (GPS). With an AVL system, central dispatch can view the location of equipped vehicles on a map, in addition to displaying specific information about each vehicle (i.e,. vehicle ID, operator, route).

Route and schedule adherence (RSA) is often determined by using AVL and schedule data in a subsystem of AVL. RSA assists drivers in maintaining their schedules and ensuring that they do not go off-route. If the system determines that the bus is running behind or ahead of schedule, the driver is notified via the MDT. The driver can then adjust the stop dwell time or layover time or increase the speed to get back on schedule, depending upon the transit agency's policy about drivers taking corrective actions to maintain their schedules.

Typically, a vehicle logic unit (VLU) is also part of an MDT. A VLU is an on–board computer that provides processing horsepower to support full automation, single point log-on, and all of the onboard ITS applications.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Automatic Vehicle Location System					
In-vehicle equipment (GPS, Vehicle Logic Unit)	Vehicle	$1,500	$3,000	$60	$120
Dispatch hardware (2 workstations*)	System	$20,000	$46,000	$2,000	$4,600
RSA software	System	$120,000	$150,000	$12,000	$15,000
Integration with scheduling	System	$40,000	$80,000	$4,000	$8,000

REASONS TO IMPLEMENT

- Serves as the backbone of many transit ITS applications, providing critical data to most other transit ITS systems such as automatic annunciation, vehicle component monitoring, automatic passenger counting (APC), transit signal priority (TSP), and real-time passenger information.
- Provides ability to monitor vehicles.
- Reduces response time to incidents.
- Improves on-time performance and reliability.
- Improves fleet utilization.

CONSIDERATIONS/ REQUIREMENTS

- Requires robust data communications system.

Automated Scheduling and Dispatch Software

Automated scheduling and dispatch software help to manage BRT vehicles and ensure the proper level of service. Transit fixed-route scheduling software applications help transit agencies with route planning and restructuring and "runcutting." Automated scheduling software allows agencies to produce the most efficient vehicle and operator/crew schedules. Increasingly, scheduling software products are being integrated with each other and with other technologies (CAD, AVL) for additional benefits. When used in combination, these applications reduce the need to re-enter data and makes data generated by each application available to all other applications. (See previous sections on AVL and CAD for more information on these technologies.)

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	**High**	**Low**	**High**
Fixed-Route Scheduling Software					
Software	System	$120,000	$300,000	$12,000	$30,000
Hardware	System	$10,000	$10,000	$400	$400
Interface of CAD to scheduling software	System	$20,000	$50,000	$2,000	$5,000

Reasons to implement:

- Improves dispatcher efficiency.
- Reduces fleet requirements.
- Better utilization of routes and scheduling.
- Reduces operating costs (reduced non-revenue time).
- Reduces operators over-time (better runcutting).

Considerations/requirements:

- Cost may not be justified for small agencies that have fewer than 7 or 8 routes (or fewer than 15 vehicles).

**Minimum of two (one serves as a backup).*

Automated Passenger Counters (APCs)

Automated passenger counters (APCs) automatically count passengers as they board and alight transit vehicles. With the introduction of GPS-based AVL systems, the integration of APC systems with AVL provides bus-stop level ridership data. In cases where a transit agency cannot invest in APCs for the entire fleet, APCs are deployed on 15-20 percent of the vehicles in a fleet. The vehicles are then rotated on different routes as needed.

An APC system creates an electronic record at each bus stop, typically including stop location, stop date/time, time of doors opening/closing, number of passengers boarding, and number of passengers alighting. These records can be downloaded at the end of the day in the garage or in real-time using the data communication system. If the latter is done, the data can be used for operations management purposes. The main technology used for passenger counting is infra-red sensors mounted in the doorway that counts people passing through the infra-red beams.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Automated Passenger Counters					
APC on-board	Vehicle	$2,500	$6,000	$100	$250
APC software	System	$50,000	$80,000	$5,000	$8,000
Interface to AVL	System	$15,000	$25,000	$1,500	$2,500

REASONS TO IMPLEMENT

- Improved and timely data for the planning department; combining APC data with a base map, route alignments, and fare information allows planners to more easily assess ridership, segments of routes experiencing overloads or low ridership, and non-productive routes/segments.
- Improves revenue control.
- Helps improve schedule efficiency.
- Reduces cost of collecting ridership data.

CONSIDERATIONS/ REQUIREMENTS

- If not all vehicles are equipped with APCs, then APC-equipped vehicles will need to be continuously rotated on different routes and across different time periods to capture all ridership data.
- Requires data maintenance and correction.

Vehicle Component Monitoring System

A vehicle component monitoring (VCM) system uses sensors to monitor various vehicle components and report on their performance and send warnings of impending (out-of-tolerance indicators) and actual failures. Components such as the engine, transmission, anti-lock brakes, and various fluid levels can be continuously monitored while the bus is in operation. By keeping track of component status with daily reports, maintenance personnel can perform preventive maintenance before a minor problem becomes major.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Vehicle Component Monitoring System					
VCM in-vehicle	Vehicle	$1,800	$2,500	$80	$100
VCM software	System	$20,000	$40,000	$2,000	$4,000
Interface to MDT	Vehicle	$200	$250	$20	$25

- Reduces maintenance costs.
- Reduces time that vehicles are out of service.
- Improves passenger convenience since abrupt service interruptions, due to mechanical problems, are significantly reduced.

- Requires data communication system and on-board mechanical monitoring systems that are capable of collecting and transmitting exception data.
- May be difficult to retrofit older vehicles with no electronic sensors.

Passenger Information Systems

Passenger information systems provide customers with information regarding BRT services. These systems can improve passenger satisfaction and reduce wait times, thus increasing ridership. For transit agencies, passenger information systems often lessen the burden on staff who provide customer information through traditional channels such as telephone. Passenger information systems also have spin-off benefits:

- ✧ Transit personnel frequently use the same real-time information systems to monitor the reliability of their services.
- ✧ The systems can be a source of revenue through the sale of advertising time and space on information media.

Passenger information can be static or real-time and can be categorized as to the location of the passenger in the "travel chain": pre-trip, en-route, station/terminal, and in-vehicle. These systems disseminate the information via a variety of media including the Internet, wireless devices, kiosks, dynamic message signs (DMS), on-board electronic signs, public address system, or an interactive voice response (IVR) system.

Significant advances have been made in the area of integrated regional traveler information systems, in particular, the introduction of the 511 telephone number, designated by the Federal Communications Commission for states and local jurisdictions to provide traveler information in the U.S. Travelers using 511 receive access to transit, traffic, and other related information. The service is usually provided free of charge.

Passenger Information Systems

Pre-Trip Passenger Information

Pre-trip transit information systems provide travelers with information to assist them in making decisions about their choice of transportation mode, route, and departure time before they embark on their trip. There are four main types of pre-trip information:

1) **General Service Information** includes static information about routes, schedules, maps, fares, and other service-related items.
2) **Itinerary Planning** allows travelers to obtain a detailed itinerary of their intended trip from Point A to Point B.
3) **Real-Time Information** provides travelers with up-to-the-minute information about the status of the BRT service. The information most frequently provided through these systems includes predicted arrival or departure times of vehicles, graphical representations of vehicle location, and service delays and/or disruptions.
4) **Multimodal Traveler Information** provides information on multiple modes of travel, including traffic and transit, in a region.

These systems often combine real-time and static data from one or more transportation services. Several types of dissemination media deliver information to passengers: Interactive Voice Response (IVR) telephone system, 511 information number, cell phones, Personal Digital Assistants (PDAs), and computers.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Web Site Enhancements					
Development	System	$30,000	$80,000	$3,000	$8,000
Hardware	System	$4,000	$8,000	$160	$320
Interactive Voice Response System					
Hardware	System	$4,000	$8,000	$160	$320
Software	System	$100,000	$200,000	$10,000	$20,000

REASONS TO IMPLEMENT

- Reduces call volumes to customer service agents.
- Reduces need for customer service agents.
- Increases breadth of customer information.
- Increases customer satisfaction.
- Improves quality of information since it is more rigorously maintained and updated and provided to customers in a more consistent manner than when relying solely on customer service agents providing information.
- Increases travel flexibility/choice.
- Reduces number of customer complaints.

CONSIDERATIONS/ REQUIREMENTS

- Information must be maintained.
- Real-time arrival/departure systems require an AVL system to be in place.

En-Route Passenger Information

En-route information is provided to customers on their way to a BRT station/terminal or while waiting for their vehicle. Just as travelers benefit from information before embarking on a trip, information provided en-route is no less critical. Providing real-time arrival or departure time at stations and/or stops has been shown to reduce traveler anxiety.

En-route information is made available through mobile telephone or web-enabled handheld devices. Information can be provided in one of two modes via wireless devices: push or pull. In the case of information push, real-time information (e.g., service delays) is sent as an email or text message to devices such as mobile telephones, PDAs, and alphanumeric pagers. The pull mode allows users to use their web-enabled devices to access the Internet and request specific information from a transit agency's website.

Examples of en-route information use include:

- Park-and-ride passengers can check parking availability and/or the departure times of the next BRT vehicle.
- Passengers waiting at a BRT stop can check the arrival time of the next BRT vehicle.
- Passengers on their way to a BRT station can check if they have missed the last vehicle.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Wireless Service					
Development	System	$30,000	$50,000	$3,000	$5,000
Hardware	System	$5,000	$15,000	$200	$600
Interface with 511	System	$10,000	$20,000	$1,000	$2,000

REASONS TO IMPLEMENT

- Reduces anxiety for customers when they are informed of the status of their vehicle.
- Reduces call volumes to customer service.
- Increases customer satisfaction.
- Improves quality of information.
- Increases travel flexibility/choice.
- Reduces number of customer complaints.

CONSIDERATIONS/ REQUIREMENTS

- Information (schedules, arrival/departure, delays, etc.) must be maintained.
- Requires an AVL system to be in place.

Station/Terminal Passenger Information

Providing transit information at a BRT stop or station plays a significant role in keeping travelers informed about the status of their vehicle and directing them to the correct stops, platforms, or bays. Real-time or dynamic information describing current transit operations includes updates on delays, incidents, and service diversions along transit routes, as well as estimated vehicle arrival or departure times for stops along the routes.

Station/terminal information can be provided to passengers through Dynamic Message Signs (DMS). DMSs are electronic displays used at stops/stations to indicate the arrival or departure times of vehicles, as well as delay information. The location of the signs and size of characters should be in accordance with the ADA Accessibility Guidelines. DMS can be powered by electricity or solar power.

State-of-the-art kiosks with touch screens allow users to navigate through static and dynamic information by simply touching selected information on the screen. Kiosks may provide users with a variety of transit and non-transit information such as schedules, route maps, fares, weather, events in the area, and traffic information. Kiosks are usually placed indoors at locations that have a high volume of foot traffic.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Station/Terminal Passenger Information					
Electronic display	Stop/station	$4,000	$10,000	$160	$400
Interface with AVL	System	$25,000	$50,000	$2,500	$5,000
Prediction software	System	$25,000	$50,000	$2,500	$5,000
Kiosks	Kiosk	$4,000	$10,000	$160	$400

REASONS TO IMPLEMENT

- Improves perception of service quality.
- Increases customer satisfaction.
- Improves quality of information.
- Increases travel flexibility/choice.
- Reduces number of customer complaints.

CONSIDERATIONS/ REQUIREMENTS

- Requires maintenance of information.
- Requires an AVL system to be in place.
- Requires connection to the communications data system from signs and shelters.
- Requires provision of power to signs and shelters (can be offset by using solar-powered elements).

In-Vehicle Passenger Information

In-vehicle information usually includes information on the next stop, vehicle schedule, transfers, or delays. This can be accomplished using an automated annunciation system (AAS), consisting of dynamic message signs (DMS) on-board the vehicle and an audio announcement of the same information displayed on the on-board DMS.

An AAS requires techniques to monitor the vehicle's location along the route so the upcoming stop name can be announced just prior to the vehicle arriving at the stop. Information beyond next-stop announcements requires that the system obtain information on the predicted vehicle arrival time at the next station/stop, receive data on other vehicles along the route, and display information on board the vehicle regarding arrival at the next stop and transfer information. An AAS is often linked to speakers on the outside of the bus to announce the route number, name, and destination of the vehicle to passengers at bus stops.

In-vehicle passenger information may provide additional benefits:

- Can be utilized to display and announce advertisements, making it a potential source for additional revenue.
- Video displays on-board BRT vehicles may provide entertainment to riders and encourage more people to use the BRT service. Each BRT vehicle may have two or more video displays connected to the Internet and may broadcast weather, news, local information, or short movies for entertainment purposes. The system may be a source of income if an agency elects to display advertisements.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Automatic Annunciation System					
Annunciator	Vehicle	$2,500	$3,500	$100	$140
In-vehicle display	Vehicle	$1,000	$1,500	$40	$60
Fixed-end equipment	System	$100,000	$160,000	$4,000	$16,000
Interface to AVL	System	$25,000	$25,000	$2,500	$2,500
In-vehicle video display					
Display units (2 per vehicle)	Vehicle	$2,000	$4,000	$80	$160
Fixed-end equipment	System	$5,000	$10,000	$200	$400

REASONS TO IMPLEMENT

- ADA requires that public transit providers announce all major stops, intersections, and landmarks. Generally, drivers are required to make these announcements. In many agencies, AAS are used to perform this required function, eliminating the need for drivers to make the announcements.
- Increases customer convenience.
- Increases customer satisfaction.
- Increases passenger safety.
- Reduces driver responsibilities.
- Improves navigation of the transit system by individuals with visual and hearing impairments and/or infrequent transit users.

CONSIDERATIONS/ REQUIREMENTS

- Stop locations, stop names, and route numbers and names will need to be kept current.
- Buses with in-vehicle display signs that are not compatible with an AAS will need to be replaced (thus inflating the deployment cost).
- Requires an AVL system for automatic stop annunciation system.

Safety and Security Systems

On-Board Silent Alarm

On-board silent alarms consists of a push button that is located in a discrete location near the driver's seat of the vehicle. This silent alarm button is used by the driver whenever he/she is in danger. The alarm alerts the dispatchers without letting passengers or an individual who is perpetrating a crime know. These systems allow for quicker response to incidents and criminal activity.

After the silent alarm has been activated, the following steps can take place:

- If it is integrated with an AVL system, the dispatcher's AVL map display will zoom in on the vehicle and monitor the vehicle constantly.
- An audible alarm will sound in the dispatching office until a dispatcher acknowledges the silent alarm condition.
- A subtle indicator is displayed on the MDT to let the driver know that his/her alarm has been received.
- A message such as "Call 911" can be displayed on the exterior sign for others to see.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Silent Alarm System					
Hardware	Vehicle	$200	$400	$10	$20
Software	System	$2000	$10000	$200	$1000

REASONS TO IMPLEMENT

- Ability to precisely locate a BRT vehicle that is involved in an incident and send assistance quickly to the scene.
- Improves safety and security of drivers and passengers.
- Reduces response time to incidents.
- Reduces number of incidents.

CONSIDERATIONS/ REQUIREMENTS

- Requires data communications and AVL for implementing a silent alarm system.

On-Board Voice Monitoring

An on-board voice monitoring system is usually an add-on to the silent-alarm system. When an emergency alarm is activated, a covert microphone installed on-board allows dispatchers to listen in to on-board activities to determine the nature of the problem and then request the appropriate assistance. The covert microphone transmission cannot be initiated by the dispatcher; it is activated only via the driver's activation of the silent alarm.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
Covert Microphone System					
Hardware	Vehicle	$200	$400	$10	$20

REASONS TO IMPLEMENT

- Allows determination of the nature of the problem when a silent alarm is activated so to request the appropriate assistance.
- Improves safety and security of drivers and passengers.
- Reduces response time to incidents.
- Reduces number of incidents.

CONSIDERATIONS/ REQUIREMENTS

- Requires on-board data communications infrastructure.

On-Board Video Monitoring

On-board cameras provide remote monitoring and recording of the passenger environment on transit vehicles. Cameras are usually mounted to provide complete coverage of the BRT vehicle interior and may be mounted to view door wells, as well as the road through the front windshield.

On-board cameras are gaining popularity with transit agencies as a form of crime deterrence and can be used to review incidents that may have taken place on-board. Also, cameras can provide information on driver behavior by recording drivers' actions. When the behavior includes a traffic violation, such as running a red light or a stop sign, a camera can identify or verify such actions. Further, camera images can be used to review the seconds just prior to an accident to determine fault.

Video monitoring can be done in real-time utilizing a high-bandwidth communication system. However, this method is practiced on a very limited basis as it requires large bandwidth. Thus, video images often are recorded on media such as video cassettes using digital video recorders (DVRs). The images can be retrieved for reviewing and/or making prints.

System/Subsystem	Unit	Capital Cost Range		Annual O&M	
		Low	High	Low	High
On-Board Video Monitoring System					
Cameras	Vehicle	$8,000	$10,000	$320	$400
Viewing station	System	$10,000	$15,000	$400	$600

REASONS TO IMPLEMENT

- Improves safety and security of drivers and passengers.
- Reduces vandalism costs.
- Reduces insurance costs.
- Increases sense of security.
- Reduces number of incidents.

CONSIDERATIONS/ REQUIREMENTS

- Having a complete coverage of the interior of the bus requires several cameras, which may be expensive for some smaller agencies.

Effects of ITS Elements on System Performance and Benefits

System Performance

Exhibit 2-11 summarizes the links between the ITS technologies options and the BRT system performance indicators and system benefits described in Chapter 1. These links are explored further in Chapters 3 and 4.

Exhibit 2-11: Summary of Effects of ITS Elements on System Performance

	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Transit Vehicle Prioritization • Optimization of Signal Timing/Phasing • Station and Lane Access Control • Transit Signal Priority	Transit vehicle prioritization minimizes congestion and signal delays, improving travel times over local service and reducing wait times.	Transit signal priority, and to a lesser degree optimization of signal timing/phasing, facilitate schedule adherence and recovery.	Faster speeds enabled by signal priority enhance image.	Bus operators provide presence on all vehicles. Fare inspectors provide additional presence on vehicles and at stops/ stations.	Vehicle prioritization increases speed and throughput of running ways.	
Intelligent Vehicle Systems • Collision Warning • Precision Docking • Lane-Keeping Assistance Systems	Precision docking allows for faster approaches to stations and reduced dwell times. Guidance may increase travel speed.	Precision docking facilitates boarding and reduces dwell time variability.	Precision docking and guidance promote an image of BRT as advanced or cutting-edge.	Affects service quality only.	Precision docking limits delays at stations, increasing throughput Guidance systems increase travel speed, also increasing throughput	Guidance systems reduce lane crosswidth, providing more space for sidewalk access facilities. Precision docking may enhance boarding and alighting by eliminating the gap between vehicle and station.
Operations Management Systems • Computer Aided Dispatch (CAD) • Automatic Vehicle Location (AVL) • Automated Scheduling and Dispatch Software • Automated Passenger Counters (APC) • Vehicle Component Monitoring System	Active operations management maintains schedules, minimizing wait time.	Active operations management focuses on maintaining reliability.		Vehicle tracking systems enable monitoring of vehicles. Vehicle health monitoring alerts operators and central control of vehicle malfunction.	Operations management and proper service planning ensures that capacity matches demand. Systems allow quick response to resolve incidents that could cause bottle-necks.	Vehicle health monitoring alerts agency of lift or ramp malfunction. Automated Vehicle Location systems enable the implementation of Automated Voice Annunciation (AVA).

Exhibit 2-11: Summary of Effects of ITS Elements on System Performance (cont'd.)

	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Passenger Information Systems • Pre-Trip • En-Route • Station/Terminal • In-Vehicle	Effective pre-trip information coupled with reliable service minimizes wait time. Wayside/in-terminal information minimizes wait time perceptions.	Passenger information allows for notices of service interruption, increasing service reliability and perceptions of reliability.	Passenger information systems enhance brand identity and provide a channel to communicate with customers.	Passenger information systems allow for communication of security threats.		Real-time passenger information tools must be designed to be used and understood by all passengers.
Safety and Security • On-Board Silent Alarms • On-Board Voice Monitoring • On-Board Video Monitoring				Safety and security systems facilitate active management of the BRT system, deterring crime and enabling responses to incidents.		

Exhibit 2-12: Summary of Effects of ITS Elements on System Benefits

	Higher Ridership	Capital Cost Effectiveness	Operating Cost Efficiency	Transit Supportive Land Delevopment	Environmental Quality
Transit Vehicle Prioritization • Optimization of Signal Timing/Phasing • Station and Lane Access Control • Transit Signal Priority	Faster speeds, especially in contrast to other traffic, and greater reliability attract ridership.		Faster speeds result in operating cost efficiencies		Less idling of buses generates fewer pollutants.
Intelligent Vehicle Systems • Collision Warning • Precision Docking • Lane-Keeping Assistance Systems	Advanced features that enhance BRT system image may attract ridership.	Fewer accidents increase fleet capital cost effectiveness, reduce spare radio required.	Precision docking and lane keeping assistance may reduce dwell time increasing operating cost efficiency. May also reduce insurance costs. Collision warning and lane-keeping assistance systems may reduce maintenance costs and vehicle out-of-service time, as well as insurance costs.	.	
Operations Management Systems • Computer Aided Dispatch (CAD) • Automatic Vehicle Location (AVL) • Automated Scheduling and Dispatch Software • Automated Passenger Counters (APC) • Vehicle Component Monitoring Sys-tem	Operations management systems can improve reliability, which may increase ridership.	Scheduling and dispatch software may reduce fleet requirements by enabling more efficient use of resources. Cost may not be justified for small agencies that have fewer than 7 or 8 routes (or fewer than 15 vehicles).	Scheduling and dispatch software may reduce operators' over-time. Enabling better management of finite resources increases operating efficiencies. APCs provide valuable planning information for BRT services. Reduces cost of collecting ridership data.		Vehicle component moni-toring may reduce environmental impacts of undetected engine or transmission problems.
Passenger Information Systems • Pre-trip • En-route • Station/Terminal • In-Vehicle	Advanced features, such as real-time passenger information displays, enhance BRT system image and may attract ridership. Information systems also make the service easier to use, especially for new riders.	Station systems require provision of power to stations.	Quality information systems require that information must be maintained. They may reduce the need for customer service agents. Station systems require provision of power to stations; solar-based systems reduce operating costs.		

Exhibit 2-12: Summary of Effects of ITS Elements on System Benefits (cont'd.)

	Higher Ridership	Capital Cost Effectiveness	Operating Cost Efficiency	Transit Sup-portive Land Develoment	Environmental Quality
Safety and Security • On-Board Silent Alarms • On-Board Voice Monitoring • On-Board Video Monitoring	Advanced features that enhance BRT system image (safe system) may attract ridership.	Complete coverage of a bus interior requires several cameras which can be expensive. To deploy on-board voice monitoring, a data communications infrastructure must be in place.	May reduce vandalism costs and insurance costs.		

Implementation Issues

Implementation of ITS for BRT often has implications beyond just the BRT system. From project development through operation, ITS has the power to transform the way an agency performs certain tasks and business processes. Furthermore, through the need to find cooperation among functions that are typically divided across several different departments or agencies, implementation of ITS for BRT can motivate cooperation and integration of the components being implemented and the business processes behind them.

Implementation Issues During Project Development

This section discusses issues that may arise during project development when implementing ITS for BRT, including:

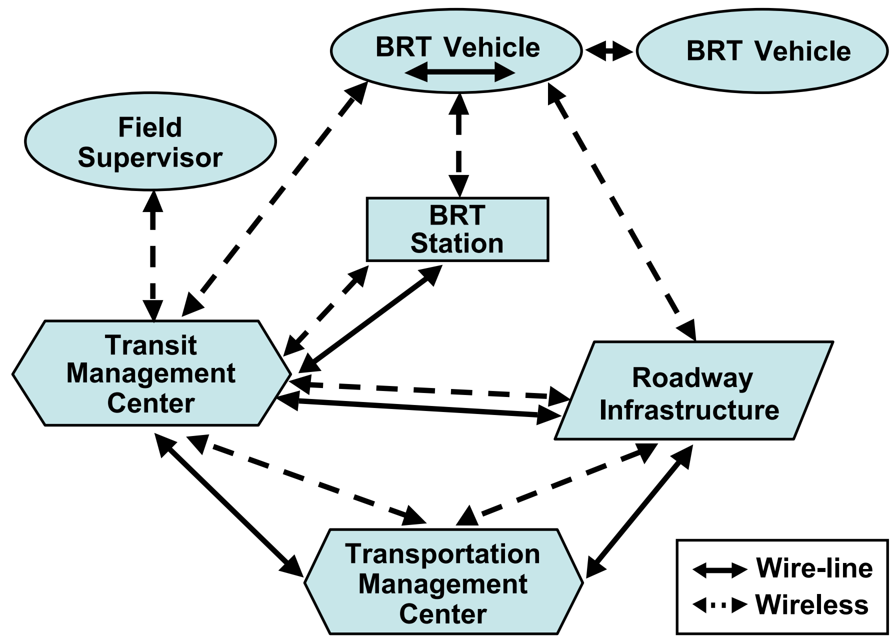
- transformation of business practices
- system integration
- requirements for a data communications system
- planning and design considerations for TSP, AVL, APC, real-time passenger information, and cameras
- relevant standards, interface requirements, and institutional requirements such as those imposed by the National ITS Architecture and the Transit Communications Interface Profiles (TCIP) effort

Transformation of Business Practices

ITS procurements have wider implications for a transit agency than procurements of other transit system components. Unlike many transit procurements, ITS deployments are not confined to a single department within the transit agency, such as payroll or maintenance—they cross over several departments. For example, an automated annunciation system requires involvement by operations, maintenance, marketing, customer service, and scheduling departments. Many ITS systems may also require coordination with external parties for information and data exchange.

Furthermore, ITS deployments differ from other transit-related systems in that they are not only for the agency's internal use but also are used and viewed by the public. For instance, an AVL system provides location and schedule adherence information for the dispatchers while also providing bus location information on the Internet for public use. As such, implementation of ITS systems creates new expectations about what information will be available to consumers and how the operation will be managed accordingly.

Exhibit 2-13: BRT Communication Schematic



Requirements for System Integration

Implementation of ITS technologies does not involve just the installation of equipment on board the vehicle, at bus stops, and at agency facilities. It also involves modifications to communications, installation of software, and integration with other agency or regional systems. Accomplishing this requires sound implementation procedures and approaches to ensure a successful deployment of the system.

Requirements for a Data Communications System

ITS technologies require a robust and reliable data communication system to function properly. For decades, transit agencies have relied on voice communications between drivers and dispatch to provide important operational information. However, a data communication system is required for most ITS technologies to be functional. This may pose a challenge to some agencies, as the availability of radio frequencies for data use is currently limited in some areas. This may require agencies to pursue alternatives such as private cellular carrier systems. A detailed analysis of current and future communications needs is a helpful step for any transit agency planning to deploy ITS technologies.

An advanced communications system (ACS) is not focused solely on the communications between the BRT vehicle and the transportation management center (TMC). While this is a vital data link, it is just one of the many communication links required for BRT system integration. Exhibit 2-13 provides a schematic of a typical communication system and the interactions among the various elements of a BRT system.

As indicated, an ACS is the foundation of a successfully deployed ITS-enhanced BRT system. All ITS technologies require some form of communication among the BRT vehicle, roadside infrastructure, and transit management center. The ACS essentially provides the means for the synergies of the ITS technologies and BRT concept to come together.

System-Specific Planning/Design Considerations

Transit Signal Priority

- Intersection Infrastructure Needs—In many cases, traffic signal control cabinets and controllers (devices at intersections that control the traffic signals) will need to be upgraded or replaced all together. The modification of these traffic signal devices can add cost and time to the implementation of TSP. Each intersection may require $10,000 to $18,000 ($8,000 to $15,000 for the cabinets, $1,000 to $2,500 for the controllers, and $500 for software). Time required for design, system specification, and system manufacture can add at least 6 to 12 months.

- Cooperation with External Agencies and Municipal Jurisdictions—The successful implementation of transit signal priority depends on cooperation between the transit agency and the relevant municipal jurisdiction in charge of traffic control.

Automatic Vehicle Location

- Cooperation of Other Departments—In addition to the communications system, AVL systems can provide information in a manner that transforms certain business functions. Cooperation among various departments is, therefore, necessary.

- Departments affected can include Operations (fixed-route and paratransit), Maintenance, Scheduling, Payroll, IT, and Planning. Issues for coordination include the placement of devices on the vehicles, requirements for labor, procedures for maintenance, and the development of AVL system reports.

Automatic Passenger Counters

APC systems provide valuable data and feedback to the transit agency, and the planning department in particular. During the implementation phase, agencies need to pay particular attention to the following:

- Placement of Equipment—Placement of equipment affects the ability to accurately count the number of passengers based on the fare collection and boarding processes. Use of APCs with non-standard door configurations (e.g., with additional doors) may require modification of standard equipment and software.

- Interfacing with AVL—In some cases, an APC system has been implemented as a stand-alone system with its own GPS on buses already equipped with an AVL system, either because the APC preceded the AVL or the APC was deployed after the AVL but by a different, less expensive vendor. These situations have created duplications, higher maintenance costs, and incomplete and mismatched data. Because the APC system is not getting its ridership records “stamped” with the AVL data (including route number, run number, direction, etc.), additional post-data-collection processing will need to be done to match the APC with bus data.

- Data Downloading Options—APC data downloading options include manual downloading via a laptop, wireless data via wireless LAN, and real-time reporting. Wireless data downloading (either at a specific regular interval or in real-time) offers an efficient and convenient option for transit agencies.

- Report-Generating Software—APC systems can generate reports more quickly and in more useful formats than traditional manual surveys. An investigation of reporting capabilities and requirements (from multiple departments, in addition to planning departments) can better define requirements of the APC system at the initiation of procurement.

Real-Time Information

Real-time transit information systems include automated annunciation systems, Internet bus location and arrival information, bus stop arrival time information, and telephone-accessible information (e.g., IVR, cell phone, PDA). Real-time information system is the most, if not only, visible ITS system to the public and the one with which they can interact. Hence, a great deal of care must be taken when implementing any of these systems, as the public's trust in the information provided by these systems is at stake. If the information delivered is not accurate or reliable, riders will quickly lose faith in the system, which may impact the decision to use the transit service.

To ensure that real-time information systems are implemented properly and are providing meaningful and complete information, agencies need to consider the following implementation approaches:

- Deployment after AVL—Implementing real-time systems after the AVL system has been successfully launched allows for system function and interfaces to be successfully resolved, thereby allowing more reliable reporting of data and ensuring that information reported to the public can be trusted.
- Phased Deployment - Phased implementation of specific systems (such as on one route only) provides transit agencies with the opportunity to test the system at a small scale, allowing the agency to work out any arrival time prediction inaccuracies and hardware problems.
- Defining Infrastructure Needs: Defining infrastructure needs (communications and power) and making sure that they are available on site are critical elements, especially when deploying the system at bus stops/shelters. A power source often is not available at shelters, or permission to draw power is necessary. Furthermore, in many cases, civil works, such as digging up and replacing the sidewalk to run power lines to the bus stop/shelter, are necessary, which can require the involvement of multiple city departments (e.g., public works, traffic and signals).

Cameras

Deployment of on-board surveillance cameras helps in reducing crime and vandalism and provides a greater sense of safety and security for the drivers and passengers. Two issues are important to consider in the deployment of such a system:

- Number and Location of Cameras—The number and location of cameras are based on the agency's assessment of what activities and events are critical to monitor (e.g., fare payment, entry/exit points, traffic, potential traffic accidents, areas of potential passenger accidents, driver's area).
- Delivery Mechanism: As with APC data, data can be downloaded manually (by removing the tape/disc and viewing it at a central location) or wirelessly. Downloading images in real-time requires a large bandwidth, which most agencies do not have and could result in interruptions to other communications systems.

Standards, Interface and Institutional Requirements

In ITS, standards for individual components and interfaces between components are critical for proper and successful implementation.

National ITS Architecture (applicable to U.S. applications)

The National ITS Architecture provides a common framework for planning, defining, and integrating intelligent transportation systems. The National ITS Architecture is not a design tool; it defines the framework around which different approaches to design and implement systems could be developed, including:

- Functions (e.g., gather traffic information, request a route) required for ITS.
- Physical entities or subsystems where these functions reside (e.g., roadside or vehicle).
- Information flows that connect these functions and physical subsystems into an integrated system.

The ITS architecture helps guide transportation professionals in applying standards and making deployment decisions that will result in efficiency, economies of scale, and national interoperability. The National ITS Architecture provides a common ground for a region's various agencies to integrate their ITS systems, allowing coordination at the regional level.

Benefits of using the National ITS Architecture in the design, implementation, and operation of ITS include:

- Multiple supplies—more vendors will be supplying compatible equipment, leading to competition and less expensive equipment.

- Future growth—by following an "open system" approach, the National ITS Architecture allows migration paths for future growth and expansion (i.e., upgrade subsystems instead of starting from scratch).
- Support ranges of functionality—the National ITS Architecture supports high-end and low-end features. Basic services can be provided free, while value-added services can be added on a fee basis.
- Synergy—the National ITS Architecture considers the requirements for multiple functions and allocates systems that optimally support those functions.
- Risk reduction—the National ITS Architecture's common framework reduces risk for those implementing ITS, equipment manufacturers, and consumers alike.

Transit Communication Interface Profiles

The Transit Communications Interface Profiles (TCIP) is an APTA standard development effort designed to allow separate transit system components and organizations to exchange data in a plug-and-play environment, particularly related to software for various transit applications. TCIP encourages transit agencies and transit suppliers to create standardized, tailored interfaces. TCIP is applicable to all transit modes and services including BRT.

TCIP is based on the earlier NTCIP work performed by ITE, AASHTO, and NEMA and is published as the NTCIP 1400-Series Standards. TCIP extended the NTCIP Standards to include a Concept of Operations, Model Architecture, Dialog Definitions, and a rigorous, modular approach to conformance. Development of both the TCIP and the earlier NTCIP was sponsored by the U.S. DOT's Intelligent Transportation Systems Joint Program Office.

In 1996, TCIP was launched, and ITE was selected to develop the standards. In 1999, Phase 1 of TCIP (TCIP1) was completed with the help of more than 800 volunteers. TCIP1 established a transit data interface framework and eight business area object standards. A list of TCIP1 standards is contained in Exhibit 2-14.

In March 2000, Phase 2 of TCIP (TCIP2) was launched. TCIP2 is sometimes referred to as the "dialogues" phase of TCIP because it focuses on the details of information exchange (messages) within and between transit applications of ITS. TCIP2 pays particular attention to the issue of messaging requirements for communications between different computing platforms since it is not realistic to expect the entire transit industry to adopt a single standard platform. Therefore, the project includes transit-specific profiles to existing applications and communications standards. The goal of TCIP2 is to develop the transaction sets, application profiles, and implementation tools. A set of guidebooks is being developed to test and implement TCIP standards.

Exhibit 2-14: TCIP Standards

Code	Title
NTCIP 1400	Framework Document
NTCIP 1401	Standard on Common Public Transportation (CPT) Objects
NTCIP 1402	Standard on Incident Management (IM) Objects
NTCIP 1403	Standard on Passenger Information (PI) Objects
NTCIP 1404	Standard on Scheduling/Runcutting (SCH) Objects
NTCIP 1405	Standard on Spatial Representation (SP) Objects
NTCIP 1406	Standard on On-Board (OB) Objects
NTCIP 1407	Standard on Control Center (CC) Objects
NTCIP 1408	Fare Collection Business Area Standard

Implementation Issues During Operation

This section discusses issues that may arise during the operation of the BRT project, including:

- Labor requirements
- Institutional and business process requirements
- Initial and ongoing training requirements
- Reliability and maintainability

Labor Requirements

The primary purpose of ITS technologies is to help transit agencies improve efficiencies, reduce cost, and provide better information. These benefits, however, often come at the cost of additional labor needs. ITS transit systems have many components that need to be routinely maintained and/or updated, which adds additional burden on the maintenance and/or operations staff. For example, updating schedules and information to be displayed onboard buses and/or wayside are additional tasks that need to be performed by agency staff. Moreover, ITS systems tend to generate a wealth of data that is useful to many areas within the transit agency. Producing these reports and performing data analysis are also additional efforts to be carried out. Thus, when deploying any of the ITS technologies stated earlier, it is crucial for the transit agency to figure out how these technologies will impact its staffing. If additional staff will be required to support these deployments, then the agency will need to include that in their budget. In addition to the possibility of having to augment staff, some of the existing staff will need to be trained on how to use the new technologies.

Institutional/Business Process Requirements

Deploying ITS technologies quite often entails some changes as to how an agency performs certain tasks. For example, if BRT vehicles provide on-board automated annunciations, then stop and route information will need to be kept up-to-date and downloaded to vehicles whenever any change to any route is made. Similarly, any new BRT stop will need to be geocoded, a practice that may not have been required prior to ITS deployments. In addition, data generated from the ITS systems will need to be disseminated within the agency, requiring a process of how to create reports, when to create them, and which staff is to receive what report.

Initial and Ongoing Training Requirements

Training of personnel that will be using the system is vital to any technology deployment. Dispatchers and drivers should receive comprehensive training before the AVL system is in place and should receive refresher training a few weeks after the system is live. In some cases, elementary training may be needed by dispatchers who may not be computer-literate.

Reliability/Maintainability

ITS technologies need to be well maintained to deliver the expected benefits. Given that some ITS technologies are used by the public to help them navigate the transit system, keeping these technologies well maintained and properly functioning is crucial. Disseminating incorrect real-time information due to a non-functioning GPS unit or outdated schedule will have severe negative consequences on the reputation of the service.

Experience with BRT and ITS

Summary of Implementation

Overall, ITS technologies have the potential to improve BRT system performance by leveraging investment in physical infrastructure.

Among the 18 U.S. BRT systems presented in Exhibit 2-15, all are either currently using or are planning to use ITS technologies. Implementation of an Automatic Vehicle Location system, real-time travel information, transit signal priority, and security technologies are the most widespread applications of ITS.

Transit signal priority is the primary Transit Vehicle Prioritization technology used in the U.S., with 11 of the 18 systems installing TSP on at least some intersections. Only one, the Silver Line in Boston, uses access control, while the Cleveland HealthLine and Eugene EmX use signal timing/phasing optimization.

The implementation of intelligent vehicle system technologies is rare among current U.S. BRT systems. The Las Vegas MAX system incorporated precision docking through optical guidance. However, the system is no longer used because of significant maintenance costs due to local weather conditions; MAX currently relies on manual docking guided by the curb. Cleveland is installing mechanical docking guidance on the median guideway stations of its HealthLine BRT.

All U.S. BRT systems use Operation Management Systems technologies . Almost all systems in Exhibit 2-15 have implemented or are implementing some type of AVL system. Computer-Aided Dispatch systems are regularly implemented with AVL systems. Automated Scheduling and Dispatch Software, Automated Passenger Counters, and Vehicle Component Monitoring Systems have also been implemented in some systems, but are less widespread than AVL.

Almost all U.S. BRT systems have installed some passenger information system technologies. Of particular note, 14 of the 18 systems below have or are planning to implement electronic information displays at stations.

In the U.S., security and safety technologies are becoming more common, with half of the BRTs using some kind of on-board alarm or monitoring system.

Outside of the U.S., real-time passenger information at stations is the most commonly-used ITS element, with almost every system in Exhibit 2-15 employing or planning real-time displays. Europe is the only region where use of Intelligent Vehicle Systems is prevalent. Mechanical guidance is most common, with one city using optical guidance and another electromagnetic guidance. Security and safety technologies are used in the three Australian cities, but few other international BRT systems report using these technologies. Finally, there is some use of TSP around the world, but it is not as commonly used as in the U.S. and Canada.

Exhibit 2-15: Experience with BRT and ITS

	Albuquerque	Boston – Silver Line		Chicago	Cleveland	Eugene	Honolulu	Kansas City
	Rapid Ride	Washington St	Waterfront	Neighborhood Express	HealthLine	EmX	Express	Main Street MAX
Transit Vehicle Prioritization								
Signal Timing/Phasing Optimization					X	X		
Station and Lane access Control			X					
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	40 / 50	Yes						31
Intelligent Vehicle Systems								
Collision Warning								
Precision Docking					Yes			
Lane Keeping Assistance Systems								
Operations Management Systems								
Computer Aided Dispatch (CAD)		X	X			X	X	
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	GPS		GSP	GPS	GPS
Automated Scheduling and Dispatch Software								
Automated Passenger Counters (APCs)	X			X				
Vehicle Component Monitoring System		AVM	X					
Passenger Information Systems								
Pre-trip		X	X	X			X	
En-route								
Station/Terminal	X	X	X		X (VMS)		X	X (Next-bus info)
In-Vehicle	X	X	X			X		
Safety and Security Technology								
On-board Silent Alarms		X						
On-board Voice Monitoring		X						
On-board Video Monitoring	X	X						

Exhibit 2-15: Experience with BRT and ITS (cont'd.)

	Las Vegas	Los Angeles	Los Angeles	Miami	Oakland	Orlando	Phoenix
	North Las Vegas MAX	Orange Line	Metro Rapid (All routes)	South Dade Busway	Rapid San Pablo Corridor	LYMMO	RAPID
Transit Vehicle Prioritization							
Signal Timing/Phasing Optimization							
Station and Lane access Control							
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	12 / 20	Planned	985		Yes		1/1
Intelligent Vehicle Systems							
Collision Warning							X
Precision Docking	Manual, with curb						
Lane Keeping Assistance Systems							
Operations Management Systems							
Computer Aided Dispatch (CAD)	X	X	X				
Automatic Vehicle Location (AVL)	GPS	GPS, Loop Detectors	GPS, Loop Detectors	X	GPS	AVL / Wi-Fi	X
Automated Scheduling and Dispatch Software		X	X	X	X		X
Automated Passenger Counters (APCs)	X	X	X		X	X	
Vehicle Component Monitoring System				X			
Passenger Information Systems							
Pre-trip	X		X				X
En-route				X		X	X
Station/Terminal		X (Next-bus VMS)	X (Next-bus VMS)	X	X	X	X
In-Vehicle	X		X	X	X	X	X
Safety and Security Technology							
On-board Silent Alarms		X	X			X	X
On-board Voice Monitoring	X	X	X			X	X
On-board Video Monitoring	X	X	X			X	X

Exhibit 2-15: Experience with BRT and ITS (cont'd.)

	Pittsburgh	Sacramento	San Jose	Halifax	Ottawa
	Busways	EBus	Rapid 522	MetroLink	Transitway
Transit Vehicle Prioritization					
Signal Timing/Phasing Optimization					
Station and Lane access Control					
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	1/1	3 / 43 (green ext)	56 / 128 (green ext, red truncation)	27	12 / 16
Intelligent Vehicle Systems					
Collision Warning	X				
Precision Docking					
Lane Keeping Assistance Systems					
Operations Management Systems					
Computer Aided Dispatch (CAD)					
Automatic Vehicle Location (AVL)			GPS	Yes	GPS
Automated Scheduling and Dispatch Software			X		X
Automated Passenger Counters (APCs)		X	X (4 veh)		X (10% of fleet)
Vehicle Component Monitoring System					Under development
Passenger Information Systems					
Pre-trip	X		X	Trip Planning	X
En-route					X
Station/Terminal	X		Real time info in development	Real Time Information	X
In-Vehicle		X	X (Automated next-stop announcement)		X
Safety and Security Technology					
On-board Silent Alarms		X	X	X	X
On-board Voice Monitoring		X	X		Planned
On-board Video Monitoring		X	X		Planned

Exhibit 2-15: Experience with BRT and ITS (cont'd.)

	York	Bogotá	Guayaquil	Pereira	Amsterdam
	VIVA	Transmilenio	Metrovia	Megabus	Zuidtangent
Transit Vehicle Prioritization					
Signal Timing/Phasing Optimization					
Station and Lane access Control					
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	All intersections along route	None	None	None	45
Intelligent Vehicle Systems					
Collision Warning					
Precision Docking					Mechanical
Lane Keeping Assistance Systems					
Operations Management Systems					
Computer Aided Dispatch (CAD)					
Automatic Vehicle Location (AVL)	X	Loop detectors, station sensors	On-board transponders	On-board transponders	
Automated Scheduling and Dispatch Software	X				
Automated Passenger Counters (APCs)	X				
Vehicle Component Monitoring System	X				
Passenger Information Systems					
Pre-trip					
En-route					
Station/Terminal	X	Nextbus displays	Nextbus displays	Nextbus displays	Real-time stop information, timetabled
In-Vehicle	X				
Safety and Security Technology					
On-board Silent Alarms	X				
On-board Voice Monitoring					
On-board Video Monitoring	Video recording (not monitoring)				

Exhibit 2-15: Experience with BRT and ITS (cont'd.)

	Caen	Edinburgh	Eindhoven	Leeds	London
	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus	Crawley
Transit Vehicle Prioritization					
Signal Timing/Phasing Optimization					
Station and Lane access Control					
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	49 Signal Priority Automatic	TSP	20	TSP in downtown areas	
Intelligent Vehicle Systems					
Collision Warning					
Precision Docking	Mechanical- Central Guidance Rail	Mechanical	Electromagnetic (for docking, not currently used)	Mechanical	Mechanical
Lane Keeping Assistance Systems					
Operations Management Systems					
Computer Aided Dispatch (CAD)					
Automatic Vehicle Location (AVL)		GPS			
Automated Scheduling and Dispatch Software		Yes			
Automated Passenger Counters (APCs)					
Vehicle Component Monitoring System					
Passenger Information Systems					
Pre-trip	Online-journey planner and timetable				
En-route					
Station/Terminal	Real-time information	Real-time information, SMS	Real-time stop information, timetabled	Real-time information, SMS	Time tabled, at Station/Stop
In-Vehicle					
Safety and Security Technology					
On-board Silent Alarms					
On-board Voice Monitoring					
On-board Video Monitoring		CCTV at station and in bus			

Exhibit 2-15: Experience with BRT and ITS (cont'd.)

	Rouen	Utrecht	Adelaide	Brisbane
	TEOR	Busway	North East Busway	South East and Inner Northern Busways
Transit Vehicle Prioritization				
Signal Timing/Phasing Optimization				
Station and Lane access Control				
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	All but 3 intersections (pre 2007 extension) Signal Priority- Automatic and Manual	Yes; Signal Priority - Automatic	Passive Priority	X
Intelligent Vehicle Systems				
Collision Warning				None
Precision Docking	Optical		Mechanical Guide Rollers on Front Axle	None
Lane Keeping Assistance Systems				None
Operations Management Systems				
Computer Aided Dispatch (CAD)				
Automatic Vehicle Location (AVL)				GPS
Automated Scheduling and Dispatch Software			X	X
Automated Passenger Counters (APCs)				
Vehicle Component Monitoring System			X	X
Passenger Information Systems				
Pre-trip			City Web Site has Trip Planning	
En-route				
Station/Terminal	Real-time stop information, timetabled	Real-time stop information, timetabled	No	Real Time Info
In-Vehicle			No	
Safety and Security Technology				
On-board Silent Alarms			Yes	
On-board Voice Monitoring			Yes	Yes
On-board Video Monitoring			Yes	Yes

Exhibit 2-15: Experience with BRT and ITS (cont'd.)

	Sydney	Beijing	Hangzhou	Kunming
	T-Ways	Line 1	Line B1	Busway Network
Transit Vehicle Prioritization				
Signal Timing/Phasing Optimization				
Station and Lane access Control				
Transit Signal Priority (Number of Intersections Applied / Total Number of Intersections)	65 on Liverpool line; Signal Pre-emption including green extension and early green	Yes	Yes	
Intelligent Vehicle Systems				
Collision Warning	None	None	None	None
Precision Docking	None	None	None	None
Lane Keeping Assistance Systems	None	None	None	None
Operations Management Systems				
Computer Aided Dispatch (CAD)				
Automatic Vehicle Location (AVL)	Loop Detectors, Liverpool only	Yes	Yes	
Automated Scheduling and Dispatch Software	X			
Automated Passenger Counters (APCs)				
Vehicle Component Monitoring System	X			
Passenger Information Systems				
Pre-trip				
En-route				
Station/Terminal	Real Time Info at Liverpool stations; termini stations only for other 2 line	Real-Time Info	Real-Time Info	Currently being implemented
In-Vehicle		Real time info	Real-Time Info	
Safety and Security Technology				
On-board Silent Alarms				
On-board Voice Monitoring	Yes	X		
On-board Video Monitoring	Yes	X		

Implementation of ITS for specific BRT applications is neither widespread or long-standing. To supplement the understanding of the potential for ITS applications, case studies of applications (many in non-BRT contexts) are presented here.

Transit Vehicle Prioritization

Signal Timing/Phasing Optimization

- ***Chicago (non-BRT)***—Pace is currently working on a signal timing optimization collaborative effort with the Illinois Department of Transportation (IDOT), the Regional Transportation Authority, and local municipal entities, which started in January 2005 and extends through 2007. The scope of work includes data collection, selection of intersections for TSP signal timing optimization, a signal timing strategies plan, design of specifications, deployment, and demonstration and evaluation. This project includes 31 signalized intersections in the vicinity of the Harvey Transportation Center. The purpose of this effort is for IDOT to have optimized traffic signals that could serve as the base condition for the comparison of TSP strategies in the future.

Station and Lane Access Control

- ***Boston***—MBTA deployed a station and tunnel access control system, an intrusion detection system that provides access only to MBTA BRT vehicles. The 20 BRT vehicles are equipped with RF (radio frequency) transponders that communicate with a receiver at the tunnel entrance, and access is provided to approved vehicles. The system has been operational since 2005. The cost of this system plus an elaborate security and surveillance system was $5 million.

Transit Signal Priority

- ***Los Angeles***—As of 2007 the LADOT implemented a TSP system used by Metro Rapid that consists of 331 loop detectors, 210 intersections equipped with automatic vehicle identification (AVI) sensors at the controller cabinet, 150 emitters-equipped buses, and central control system software at a total cost of $10 million. Loop detection technology is used to detect the presence of a bus approaching the intersection. Bus identification is detected by the AVI sensor and sent to the transit management computer located at the LADOT transportation management center. Average cost was $13,500 per signalized intersection.

In Los Angeles, the implementation of Metro Rapid also became the impetus for installing a new communication system. The system needed a way to transmit data between the BRT vehicle, traffic signals, and the transit management center to implement the TSP system. Fiber optic cables were installed, linking the traffic signals and the transit management center. Communication needs at BRT sites of planned ITS technologies will need to be analyzed and compared to current communication capabilities.

Intelligent Vehicle Systems

Collision Warning

- ***San Mateo, California (non-BRT)***—The San Mateo County Transit District (SamTrans) carried out a collision warning system demonstration project in the summer of 2005. A bus was fitted with integrated frontal and side collision warning devices. This system is being expanded to more vehicles.

- ***Pittsburgh (non-BRT)***—The Port Authority of Allegheny County installed a side object detection system from Collision Warning Systems on 100 vehicles operating out of its East Liberty garage. The system includes six sensors on each side of the bus and a sensor on the back corners. The system detects objects and provides both an audible and visual warning to the driver.

Precision Docking

- ***Las Vegas***—The Civis bus was guided by an inexpensive, computerized optical guidance system that follows white stripes painted on the pavement. However, due to lack of rainfall, the roadway needed constant cleaning of dirt and oil buildup, which degraded the contrast between the white stripes and the pavement. Hence, the system was performing irregularly and has subsequently been abandoned.

Lane-Keeping Assistance Systems

- ***Eindhoven, Netherlands***—Phileas is a 200-passenger-BRT system that is (semi-) automated. It operates on a dedicated lane, and the electronic guidance enables it to operate automatically while on its dedicated guideway. In semi-automated mode, the lateral position is controlled by the technology and the driver controls the speed.

Operations Management Systems

Implementation of operations management technologies such as CAD/AVL is often tied to system-wide implementations and is not just BRT-related. The deployments discussed below may include BRT routes operated by these agencies but are generally intended as system-wide applications.

Computer Aided Dispatch (CAD)

- ***Columbus, Ohio***—As part of its CAD/AVL procurement, the Central Ohio Transit Authority acquired Trapeze scheduling software for its fixed-route fleet (Trapeze FX and OPS).
- ***Northern Kentucky***—The Transit Authority of Northern Kentucky (TANK) deployed fixed-route operations software as part of its CAD/AVL deployment in 2003.
- ***Fairfax, Virginia***—The Connector bus service acquired fixed-route scheduling software in 2004.
- ***Woodbridge, Virginia***—The Potomac and Rappahannock Transportation Commission (PRTC) deployed MDTs on its fleet as part of its ITS deployment in 2003.

Automatic Vehicle Location (AVL)

- ***Madison, Wisconsin***—Metro Transit deployed CAD/AVL system on its 243-vehicle fleet. The system also monitors route and schedule adherence.
- ***Woodbridge, Virginia***—PRTC deployed a CAD/AVL system on its fleet of 13 flexible service and 57 express vehicles in 2003.
- ***Las Vegas***—The Regional Transportation Commission of Southern Nevada recently acquired a GPS-based CAD/AVL system, which included 296 fixed-route, 150 paratransit, and 10 supervisor vehicles.
- ***Lake Tahoe, Nevada***—The Tahoe Regional Planning Agency (TRPA) deployed a CAD/AVL system on its fleet of 47 vehicles.
- Automated Scheduling and Dispatch Software
- ***Columbus, Ohio***—In 2002, as part of its CAD/AVL procurement, the Central Ohio Transit Authority acquired scheduling software for its fixed-route fleet
- ***Madison, Wisconsin***—Metro Transit deployed a CAD/AVL system on its 243-vehicle fleet. The system provides for two dispatching workstations. Automated fixed-route scheduling software was also deployed.
- ***Kansas City, Missouri***—Kansas City Area Transit Authority (KCATA) acquired both automated scheduling software and dispatch software as part of its ITS deployment in 2003. Scheduling and dispatching software are also used for KCATA's BRT service.

Automated Passenger Counters (APCs)

- ***Las Vegas***—The Regional Transportation Commission of Southern Nevada deployed an APC system as part of its CAD/AVL deployment effort.
- ***Columbus, Ohio***—The Central Ohio Transit Authority has been using APCs since the mid-1980s, with its most recent upgrade in 2005. Data collected by the APCs are 95 percent accurate.
- ***Seattle***—The King County Department of Transportation (Metro) has been utilizing APCs since 1980. In 2000, King County Metro upgraded its APC system and increased the percentage of APC-equipped buses from 12 to 15 percent.
- ***Portland, Oregon***—Data collected by Tri-Met's APCs are 98-99 percent accurate.

Vehicle Component Monitoring System

- ***Falls Church, Virginia***—In 2002, Falls Church equipped four of its buses with in-vehicle diagnostics monitoring system. This system is a network of sensors connected to critical vehicle systems (e.g., transmission) and provides data that can be used by a maintenance system.
- ***Washington, D.C.***—WMATA Metrobus equipped 164 new CNG and articulated buses with in-vehicle diagnostics monitoring system. At the end of the day, as buses return to their garages, data collected on critical components in the vehicle (e.g., transmission "health") are downloaded from each bus.

Passenger Information Systems

Pre-Trip Passenger Information

- ***Chicago***—The Regional Transportation Authority is developing a Multi-modal Trip Planning System (MMTPS) that will integrate existing single-mode trip planners and real-time travel information systems in the Chicago region. The MMTPS will use ITS standards to provide travelers with real-time comparative door-to-door travel instructions over the Internet.
- ***Seattle***—King County Metro's BusView Internet application provides information on the location of buses. The application allows the user to set an "alarm" at any point along a bus route; when the bus reaches that point, a message is sent to the user alerting him/her that the bus has reached the requested point along the route.
- ***Salt Lake City, Utah***—The Utah Transit Authority's (UTA) website provides travelers with comprehensive pre-trip information, such as detailed itineraries and a list of buses that are affected by detours. Also, users can download UTA's "On the Go" PDA application to access bus schedules, hours of service, fares, and other information.
- ***Washington, D.C.***—WMATA's IVR phone system was introduced in November 2002, making it the first transit agency in the country to offer fully-automated, voice-enabled trip planning. The IVR application informs riders about how to travel to their destinations in the Washington metropolitan region by bus or rail. It provides several alternatives for each trip request, including walking directions and fare information. The current application covers most of the bus and rail operators in the region.
- ***San Francisco***—Bay Area Rapid Transit (BART) provides its QuickPlanner for an Apple iPod, which includes BART schedules, station information, a BART system map, and update notifications.

En-Route Passenger Information

- ***Washington, D.C.***—Metrorail eAlerts, provided by WMATA, is an e-mail subscription service to notify customers of Metrorail service disruptions. Additionally, WMATA provides customers with the ability to generate detailed trip itineraries via its website.
- ***Woodbridge, Virginia***—PRTC introduced an e-mail alert system in December 1999. The system provides information on any incident that may affect transit service. E-mail alerts are sent to all subscribers and can be received via computer, cell phone, or PDA.

Station/Terminal Passenger Information

- ***Los Angeles***—LACMTA deployed a real-time arrival information system as part of its Metro Rapid BRT system. The deployment includes 44 DMSs at various stops that display the actual arrival time of buses.
- ***San Luis Obispo, California***—SLO Transit provides real-time arrival information at its bus stops. The DMSs used for this system are all solar-powered.
- ***Williamsport, Pennsylvania***—River Valley Transit implemented a unique information system at its downtown Transit Center. The system uses two DMSs to display the bay number for each bus as well as to alert passengers when a bus is about to depart.
- ***Portland, Oregon***—Tri-Met's Transit Tracker provides real-time bus arrival information at numerous bus stops and MAX stations throughout its service area.
- ***Washington, D.C.***—WMATA deployed its Passenger Information Display System (PIDS) in 2001. The system was operational at all Metrorail stations with more than 400 signs. DMSs at Metrorail stations display arrival times of the Metro trains in a countdown fashion, e.g., "Red Line/6 Cars/4 Minutes." The DMSs are also used to display time and to provide information during an emergency.

In-Vehicle Passenger Information

- ***Columbus, Ohio***—Central Ohio Transit Authority (COTA) completed its installation of an Automated Vehicle Anunciation (AVA) System in 2005. In addition to announcing and displaying upcoming stops inside the bus, the system announces and displays the route number and direction on the exterior of the bus.
- ***Madison, Wisconsin***—Metro Transit equipped its buses with automatic annunciation as part of its ITS deployment in 2003.

- ***Los Angeles***—As part of its Phase II deployment, LACMTA deployed an AVA system on its bus fleet in 2005.
- ***San Antonio***—VIA Metropolitan Transit equipped its entire fleet with an integrated in-vehicle information system. Each vehicle is equipped with audio/visual units to announce the next stop.

Safety and Security Systems

On-Board Silent Alarm

- ***Denver***—Assaults on bus operators and passengers dropped by 20 percent after the Denver RTD implemented its silent alarms and covert microphones.
- ***Columbus, Ohio***—All COTA fixed-route vehicles were retrofitted with silent alarm in 2002.
- ***Phoenix***—Valley Metro equipped its fleet with on-board silent alarm system in 2005.
- ***Los Angeles***—LACMTA equipped its buses with silent alarm system as part of its CAD/AVL deployment in 2004.

On-Board Voice Monitoring

- ***Denver***—Denver RTD implemented its AVL/CAD system which included silent alarms and covert microphones on-board its buses.
- ***Phoenix***—Valley Metro equipped its fleet with on-board silent alarm systems in 2005.
- ***Los Angeles***—LACMTA equipped its buses with silent alarm systems as part of its CAD/AVL deployment in 2004.

On-Board Video Monitoring

- ***Monterey, California***—Monterey-Salinas Transit deployed a comprehensive on-board and external video surveillance system in 2004 and 2005. This system has led to the identification and conviction of criminals both on-board and outside vehicles.
- ***Philadelphia***—Anecdotal information from SEPTA and other transit systems indicate that the total dollar amount of claims can be reduced by 10-20 percent by having video cameras and recorders on-board transit vehicles.

Relationship between the Element and Demonstrated Performance

This section presents figures of demonstrated performance for various ITS technologies.

Exhibit 2-16: Demonstrated Performance for Transit Vehicle Prioritization Systems

ITS Option	Performance Measure	Case of Demonstrated Performance
Signal Timing/Phasing Optimization		N/A
Station Lane Access Control		N/A
Transit Signal Priority	Travel Time Savings	**Seattle** : King County DOT implemented a 2.1-mile TSP system on Rainier Avenue. Average signal delay was reduced from 7.7 seconds to 3.3 seconds (57% reduction). Effects to side street and overall intersection delay were insignificant. **Los Angeles**: LADOT and LACMTA estimate up to 25% reduction in bus travel times due to the TSP system. **Phoenix** : Deployed TSP at seven intersections, reducing signal delay for buses by 16%. Impact on cross traffic was minimal. **Tacoma, Washington**: Combination of TSP and signal optimization reduced transit signal delay ~40% in two corridors (221 intersec-tions). **Portland, Oregon**: TriMet experienced 10% improvement in travel time. **Chicago** : PACE buses had an average 15% reduction (3 mins) in running time using TSP at 22 intersections. Actual running time reductions varied from 7% to 20% depending on the time of day.
	Reliability	**Portland, Oregon**: TriMet experienced 19% reduction in travel time variability. Due to increased reliability, TriMet has been able to reduce travel time.
	Capacity	**Portland, Oregon**: TriMet avoided adding 1 bus by using TSP.

Exhibit 2-17: Demonstrated Performance for Service Planning and Bus Operations Management Systems

ITS Option	Performance Measure	Case of Demonstrated Performance
Computer Aided Dispatch (CAD)		N/A
Automatic Vehicle Location (AVL)		**Hamilton, Ontario**: Hamilton Street Railway Co. increased schedule adherence from 82% to 89% after implementing AVL.
Automated Scheduling	Reliability	N/A
Automated Passenger Counters (APC)		N/A
Vehicle Component Monitoring System	Safety and Security	**Washington, D.C.**: WMATA's system reduced road calls. Metrobus VCM system identified new CNG buses with faulty oxygen sensors; bus manufacturer agreed to replace.

Exhibit 2-18: Demonstrated Performance for Passenger Information Systems

ITS Option	Performance Measure	Case of Demonstrated Performance
Pre-trip Passenger Information	Identity & Image	**Washington, D.C.**: WMATA RideGuide improved calls answered by call takers from 85% to 95%, busy/no answer complaints dropped from 40 per month in 2002 to 0 in early 2003.
En-route Passenger Information		N/A
Station/Terminal Passenger Information	Identity & Image	**Washington, D.C.**: WMATA deployed Passenger Information Display System (PIDS) in 2001at all Metrorail stations with over 400 signs. Survey indicated 93% of respondents aware of PIDS; among frequent Metrorail riders, 99% were aware of and 98% had used PIDS. Survey respondents were fairly satisfied with PIDS, only 11% not satisfied.
In-Vehicle Passenger Information		N/A

Exhibit 2-19: Demonstrated Performance for Safety and Security Systems

ITS Option	Performance Measure	Case of Demonstrated Performance
On-Board Silent Alarms	Safety and Security	**Denver**: Assaults on bus operators and passengers dropped by 20% after implementation of silent alarms and covert micro-phones. **Columbus, Ohio**: Covert alarm and AVL system credited for saving a Central Ohio Transit Authority driver's life: Driver hit covert alarm just as he suffered a heart attack; dispatchers notified instantly, location of bus identified, emergency personnel directed to exact location of bus.
On-Board Voice Moni-toring	Safety and Security	**Denver**: Assaults on bus operators and passengers dropped by 20% after implementation of silent alarms and covert micro-phones.
On-Board Video Moni-toring	Safety and Security	**Philadelphia**: SEPTA and other transit systems indicate that total dollar amount of claims can be reduced by 10% - 20% with video cameras and recorders on-board transit vehicles. **Washington, D.C.**: Surveillance cameras deployed onboard Metrobuses proved effective in three incidents-- In one, on-board camera captured image of a suspected murderer, allowing Metro police to produce a photo of suspect's face. In another, on-board camera helped WMATA prevail in legal case where a rider sued WMATA, claiming driver reckless driving caused head injuries.

Demonstrated performance data were not available for collision warning, rear-impact warning, precision docking, or lane-keeping assistance systems.

Relationship between the Element and Demonstrated Benefits

Exhibit 2-20: Demonstrated Benefits for Transit Vehicle Priority Systems

ITS Option	Performance Measure	Case of Demonstrated Performance
Signal Tim-ing/Phasing Optimization		N/A
Station Lane Access Control		N/A
Transit Signal Priority	Operating Cost Efficiency	**Los Angeles**: LADOT and LACMTA estimate savings in operating costs of $6.67 per bus per hour due to TSP system, translates to approximate savings in operating costs of $66.70 per bus per day. **Chicago**: TSP deployed at 22 intersections and more efficient runcutting, PACE realized savings of 1 bus while maintaining the same frequency of service on a weekday.

Exhibit 2-21: Demonstrated Benefits for Service Planning and Bus Operations Management Systems

ITS Option	Benefits Measure	Case of Demonstrated Benefits
Computer Aided Dis-patch (CAD)	Operating Cost Efficiency	**Ann Arbor, Michigan**: AATA estimates that its computer-assisted transfer management (CATM) software (also known as transfer con-nection protection) accounts for majority of estimated 70% reduction in voice traffic on its radio system. **Columbus, Ohio** – CAD/AVL system reduced dispatchers "busy" time by 10%, allowed more time to devote to critical tasks and provide better assistance to drivers.
Automatic Vehicle Lo-cation (AVL)	Operating Cost Efficiency	**Prince William County, Virginia**: PRTC estimated annual savings of $869,148 because of AVL system. **Portland, Oregon**: Tri-Met's AVL/CAD system produced estimated annual operating cost savings of $1.9 million, based on analysis of 8 routes typical of Tri-Met service.
Automated Scheduling	Operating Cost Efficiency	**Columbus, Ohio**: Study in 2001 showed automated CAD/AVL system resulted in 10%-15% dispatcher time savings.
Automated Passenger Counters (APC)	Operating Cost Efficiency	**London, Ontario**: London Transit saves $50,000 over manual methods per system-wide count. **Atlanta**: MARTA reduced the number of traffic checker positions from 19 to 9.
Vehicle Component Monitoring System	Capital Cost Effectiveness	**Washington, D.C.**: WMATA's system reduced road calls. Metrobus VCM system identified new CNG buses with faulty oxygen sensors; bus manufacturer agreed to replace.

Exhibit 2-22: Demonstrated Benefits for Passenger Information Systems

ITS Option	Benefit Measure	Case of Demonstrated Benefits
Pre-Trip Passenger Information		**Washington, D.C.**: WMATA's RideGuide helped Metro avoid hiring 5-10 new customer service staff every year to keep up with increased calls.
En-route passenger information		N/A
Station/Terminal Passenger Information		**Washington, D.C.**: WMATA deployed Passenger Information Display System (PIDS) in 2001at all Metrorail stations with over 400 signs. Survey indicated 93% of respondents aware of PIDS; among frequent Metrorail riders, 99% were aware of and 98% had used PIDS. Survey respondents were fairly satisfied with PIDS, only 11% not satisfied.
In-Vehicle Passenger Information	Higher Ridership	N/A

Exhibit 2-23: Demonstrated Benefits for Safety and Security Systems

ITS Option	Benefit Measure	Case of Demonstrated Benefits
On-Board Silent Alarms		N/A
On-Board Voice Monitoring		N/A
On-Board Video Monitoring	Operating Cost Efficiency	**Philadelphia**: SEPTA and other transit systems indicate that total dollar amount of claims can be reduced by 10% - 20% with video cameras and recorders on-board transit vehicles. **Washington, D.C.** - Surveillance cameras deployed onboard Metrobuses proved effective in three incidents-- In one, on-board camera captured image of a suspected murderer, allowing Metro police to produce a photo of suspect's face. In another, on-board camera helped WMATA prevail in legal case where a rider sued WMATA, claiming driver reckless driving caused head injuries.

Demonstrated benefits figures were not found for intelligent vehicle systems: collision warning, rear-impact warning, precision docking, or lane keeping assistance systems.

SERVICE AND OPERATING PLANS

Description

Role of the Service and Operating Plan in BRT

The design of the service and operations plan for BRT service affects how a passenger finds value in and perceives the service. BRT service should 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 details basic service and operational planning considerations related to the provision of BRT service. Each of the operational items discussed varies when applied in different corridors, different cities, and different regions, depending on a host of factors such as available capital and operating budget, customer demand, available rights-of-way, potential route configuration, and political environment.

Characteristics of the Service and Operating Plan

- ***Route Length***—Route length affects what locations a customer can directly reach without transferring and determines 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 passengers 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.

- ***Route Structure***—An important advantage of BRT running ways 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. Service designers of BRT systems are thus able to create tailored services and 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 riders to the BRT system. Increasing the number of choices has trade-offs with simplicity and clarity of the route structure.

- ***Service Span***—The service span represents the period of time that a service is available for use. Generally, rapid transit service is provided most of the day with high frequencies through the peak hours that allow passengers to arrive randomly without significant waits. Service frequencies are reduced in off-peak hours such as mid-day and 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 passengers. For example, peak-only service spans limit the potential passengers 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 passengers may have an option between the two services. Exhibit 2-24 describes different BRT service types and typical spans by running way type.

Exhibit 2-24: BRT Service Types and Typical Spans

Principal Running Way	Service Pattern	Service		
		Weekdays	Saturday	Sunday
Arterial Streets	**All Stop**	**All Day**	**All Day**	**All Day**
Mixed Traffic	Connecting Bus Routes	All Day	All Day	All Day
Bus Lanes				
Median Busways (No Passing)				
Freeways				
Mixed Traffic	Non Stop with Local Distributor	All Day	All Day	
Bus/HOV Lanes	Commuter Express	Peak Period		
Busways	**All Stop**	**All Day**	**All Day**	**All Day**
	Express	Day Time or Peak Period		
	Feeder Service	Day Time All Day or Non-Peak Period	Day time or All Day	Day Time
	Connecting Bus Routes	All Day	All Day	All Day

**All Day - typically 18 to 24 hours; Daytime - typically 7 a.m. to 7 p.m.; Rush Hours - typically from 6:30 to 9 a.m. and 4 to 6 p.m.; 1 feeder bus service in Off Peak and express service in Peak; see "Bus Rapid Transit - Implementation Guidelines," TCRP Report 90.*

- ✧ ***Service Frequency***—Service frequency determines how long passengers must wait for service. Tailoring service frequency to the market served is one of the most important elements in planning and operating a BRT system.
- ✧ ***Station Spacing***—BRT system operating speeds are greatly influenced by a number of operational planning issues, including the distance or spacing between stops. The spacing of stops has a measurable impact on the BRT system's operating speed and customer total travel time. Long station spacing increases operating speeds.
- ✧ ***Methods of Schedule Control***—BRT schedules can be maintained and monitored either to meet specified schedules or to regulate headways.

Service and Operations Planning Options

Route Length Options

Route lengths vary according to the specific service requirements and development characteristics of a corridor. Route lengths of less than 2 hours of total round trip travel time tend to improve schedule adherence and overall system reliability. This generally translates into route lengths a maximum of 20 miles. Keeping total round trip travel time to a minimum is desirable to avoid passengers relying on a printed schedule to use BRT services.

Route Structure Options

There are three types of BRT route structure options for consideration. With each type, higher levels of overlap with the existing transit network may bring increasing opportunity to reallocate service and achieve resource savings.

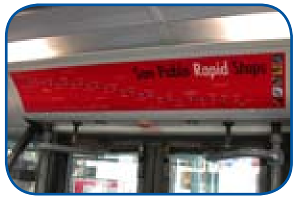
Simple route structures with just one or two route patterns are easy for new passengers to understand and, therefore, straightforward to navigate. To attract customers, they must be able to easily understand the service being offered. Service directness and linearity in routing are keys to providing customers with a clear understanding of BRT service. However, providing additional options, such as through a comprehensive route network with branching routes, gives passengers more choices, especially those passengers who might otherwise transfer. Clarity and choice are two principles that should 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.

Route Structure Options

Single Route

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 passengers at stations all along the route.



AC Transit—San Pablo, CA

REASONS TO IMPLEMENT

- Simple route structure helps customers understand service and best serves patterns of demand.
- To facilitate equal loadings on successive buses during peak (and off-peak) hours.

CONSIDERATIONS/ REQUIREMENTS

- Requires dedication of a fleet to serve the entire route, even when demand is low on certain segments.

Overlapping Route with Skip Stop or Express Variations

This is a hybrid approach that combines simple routes with some variation in service pattern. The overlapping route with skip stop or express variations provides various transit services including the base BRT service.

TEOR—Rouen, France

REASONS TO IMPLEMENT

- Retains some key advantages of simple routes while introducing alternate service patterns that can better serve certain origin-destination pairs.
- Helpful to serve several markets

CONSIDERATIONS/ REQUIREMENTS

- Works best with passing capability at stations.
- May introduce some confusion for infrequent riders and may cause congestion at stations.
- Creates variability of loads on successive vehicles.

Integrated or Network System (with Locals, Expresses, and Combined Line-Haul / Feeders)

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

MBTA—Boston, Mass.

REASONS TO IMPLEMENT

- Provides maximum choice of different types of service with a fixed infrastructure investment.

CONSIDERATIONS/ REQUIREMENTS

- Requires infrastructure treatments (e.g., passing capability at stations and dedicated lanes to prevent congestion.
- Requires strong marketing and passenger information campaigns to direct passengers to the appropriate service.

Span of Service Options

There are two service span options for BRT service.

Span of Service Options	REASONS TO IMPLEMENT	CONSIDERATIONS/ REQUIREMENTS
All Day All-day BRT service is usually provided from the start of service in the morning to the end of service in the evening. This type of service usually maintains a minimum level of service (frequency) 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. For network BRT systems, service during off-peak periods can revert to only the trunk link service to better match demand.	• Conveys to passengers that service is available and reliable.	• Requires provision of service at times when demand is especially low.
Peak-Period-Only This type of BRT span of service option provides peak-period service, offering high-quality and high-capacity-BRT-service-only when it is needed during peak hours. At other times, the base level of service may be provided by local bus routes.	• Often implemented in arterial corridors where there is established local service and where BRT service provides a faster, more reliable choice. • Implemented in corridors with heavy commute-travel orientation.	• Often requires some background service (e.g., local bus service) to ensure some level of service throughout the day. • Requires strong campaign to disseminate schedule information.

Frequency of Service Options

The frequency of service affects the service regularity and the ability of passengers to rely upon the BRT service. High frequencies (e.g., headways of 10 minutes or less) create the impression of dependable service with minimal waits, encouraging passengers to arrive randomly without having to refer to a schedule.

Station Spacing Options

BRT stations are typically spaced farther apart than stops for local service. Spacing stations farther apart concentrates passengers at stations, limiting delays to fewer locations along a route. Longer stretches between stations allow vehicles to sustain higher speeds between stations. These factors lead to overall higher travel speeds. These higher speeds help to compensate for the increased amount of time required to walk, take transit, or drive to stations.

Methods of Schedule Control

On-time performance is monitored either to meet specified schedules or to regulate headways. The two methods are described below.

Methods of Schedule Control

	REASONS TO IMPLEMENT	CONSIDERATIONS/ REQUIREMENTS
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 passengers that schedules fall at certain regular intervals.	• For services with longer headways, schedules may be appropriate so passengers can time their arrival at stations. • Well-suited to corridors with exclusive transitways that can maintain reliable times such as those with exclusive transitways or minimal congestion.	• Requires active operations management to ensure "on-time" performance.
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. Dispatchers monitor vehicle locations and issue directions to speed up or slow down to regulate headways and capacity, minimizing wait times and vehicle bunching.	• Appropriate for high frequency services to promote faster speeds and reduce waiting times.	• Requires a combination of active supervision, automated vehicle location (AVL) technology, and/or transit signal priority (TSP) to maintain regular headways.

Effects of Service and Operations Plan Elements on System Performance and System Benefits

Exhibit 2-25 summarizes the links between the Service and Operations Plans, policies, practices, and technologies and the BRT system performance indicators and system benefits identified in Chapter 1. These links are explored in-depth in Chapters 3 and 4.

Exhibit 2-25: Summary of Effects of Service and Operations Plan Elements on System Performance

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Route Length	Longer routes may decrease the need for transfers.	Shorter route lengths may promote greater control of reliability.				
Route Structure and Type • Single Route • Overlapping Route with Skip Stop or Express Variations • Integrated or Network System	Integrated route structures reduce the need for transfers. Express and Skip-Stop routes have shorter travel times than local service and can reduce systemwide travel times by spreading passenger loads and reducing station dwell times on local routes.	Express and Skip-Stop routes can prevent bus bunching and reduce variability between peak and non-peak hour operations. They can cause congestion at stations if stations are not designed to accommodate multiple vehicles.	Distinctions between BRT and other service may better define brand identity. Creating a strong image is important to avoid confusion for riders in differentiating these services. Integrated route structures may widen exposure to the brand.		Multiple services can increase operational capacity.	Integrated or network systems may reduce the number of required transfers.
Span of Service • Peak Hour Only • All Day		Wide spans of service suggest the service is dependable.	Peak-hour only service may require strong education efforts to make riders aware of service availability and schedule.	Peak-only service may require less security at stations since passengers at stations will not be isolated.		
Frequency of Service	More frequent services reduce waiting time.	High frequencies limit the impact of service interruptions. Frequent service may experience bus bunching problems.	Frequent service can make BRT appear more like some rail systems. It also makes BRT easier to use, which enhances its image as a premium service.	High frequencies increase potential conflicts with other vehicles and pedestrians. High frequencies reduce security vulnerability at stations.	Increased frequency is a key determinant of operating capacity. Service frequency is limited by system capacity (vehicle, station and running way capacities).	
Station Spacing Narrow Wide	Less frequent station spacing has a major impact on travel time by increasing overall system speeds.	Less frequent station spacing limits variation in dwell time.	Less frequent stops-and-starts make for a smoother ride, which enhances the passenger experience.			
Method of Schedule Control Schedule-Based Headway-Based	Headway-based control for high frequency operations maximize speeds.	Headway-based control may result in variability between peak and non-peak hours, while schedule-based control can make service seem unreliable if schedules cannot be maintained during peak hours.				

Exhibit 2-26: Summary of Effects of Service and Operations Plan Elements on System Benefits

	System Performance				
	Higher Ridership	Capital Cost Effectiveness	Operating Cost Efficiency	Transit-Supportive Land Development	Environmental Quality
Route Length	Service plans that are customer-responsive attract ridership and maximize system benefit		Principles appropriate to the design and scheduling of cost-efficient BRT service primarily the same as for conventional bus services. Planners need to design service that is appropriate to the level of travel demand and minimizes non-productive vehicle hours.		
Route Structure and Type • Single Route • Overlapping Route with Skip Stop or Express Variations • Integrated or Network System	Overlapping routes may cause confusion for infrequent riders, which could inhibit ridership. An integrated or network system can offer more one-seat rides which may attract more riders.			The flexible nature of BRT service plans allows BRT to expand or contract with changes in land use quickly and easily. If the BRT is designed to provide fast and convenient connections among key activity hubs in an urban or suburban area, this may help attract developer interest.	An overlapping route may reduce emissions by increasing the overall service efficiencies.
Span of Service • Peak-Hour-Only • All-Day					
Frequency of Service	High frequencies create the impression of dependable service with minimal waits, which may attract riders.				Higher frequencies can increase vehicle noise pollution created by the system operations. High frequency service that is not commensurate with ridership levels may result in higher per-passenger emissions.
Station Spacing • Narrow • Wide					Few stops mean traveling at higher speeds and reduced stoppage time, which lowers emissions.
Method of Schedule Control • Schedule-Based • Headway-Based					Headway based schedules can reduce idling and lower overall emissions.

Experience with BRT Service Plans

Exhibit 2-27 shows BRT service plans in 45 cities around the world. Most U.S. BRT systems feature a single BRT corridor replacing an existing local route or overlaid onto the same route, with fewer stops. One notable exception is the Los Angeles Metro Rapid, which consists of an extensive network of rapid bus lines overlaid onto local routes. The Latin American BRTs lie at the opposite end of the spectrum from the U.S., with extensive trunk and feeder networks replacing the local bus routes. Other regions demonstrate a variety of approaches.

Station spacing varies widely, although most are between 0.4 and 1 mile. There are some U.S. BRTs with station spacing under 0.4 miles, which is essentially comparable to local bus service spacing. A few systems that operate on HOV or highway lanes or as commuter services have very high station spacing of 3 to 4 miles.

Frequencies correlate with the running way investments, as it is possible to achieve much higher frequencies with grade-separated transitways. Typically, the BRT systems on arterials operate with headways between 9 and 15 minutes, with a few such as Boston and Los Angeles operating shorter headways in some corridors. By contrast, the dedicated running way frequencies are more likely to be 1 to 8 minutes.

Most of the BRT systems provide all-day service, with just a few operating as peak-only services. The majority are all-stop services. The cities that have built segregated busway networks, such as Ottawa, Adelaide, Brisbane, Bogotá, Guyaguil and Pereira, are able to offer multiple service options including limited stop and express service.

Exhibit 2-27: Experience with BRT Service Plans

	Albuquerque	Boston Silver Line		Chicago	Cleveland	Eugene	Honolulu
	Rapid Ride	Washington St	Waterfront Airport	Express	HealthLine	EmX	City Express
Route Structure	Overlapping route	Replaced Local Route	New service	Overlay onto Local Route	Replaced Local Route	Replaced Local Route	Overlay onto Local Route
Route Type	Limited-Stop	All Stop	All-stop	Limited	All-stop	All-stop	Limited Stop
Span of Service	All Day	All Day	All Day	All Day	all day	all day	All Day
Frequency of Service in Peak Hours (Headway in Minutes)	11	4	10		5	10	15
Frequency of Service Off-Peak (Head-way in Minutes)	11		15	9 to 12	15	30	20 - 30
Avg. Station Spacing Distance	0.87	0.22	4.45	0.47 to 0.56	0.42	0.44	0.26 - .55

Exhibit 2-27: Experience with BRT Service Plans (cont'd.)

	Honolulu	Kansas City	Las Vegas	Los Angeles	Miami	Oakland	Orlando
	County Express	Main Street MAX	North Las Vegas MAX	Metro Rapid (All routes)	South Dade Busway	Rapid San Pablo Corridor	LYMMO
Route Structure	Overlaps local route	Replaced existing route?	Overlay onto Local Route	Overlaid on local routes	Integrated Network of Routes	Overlay onto Local Route	Replaced Local Downtown Circulator
Route Type	Express	Limited Stop	Limited Stop	Limited	Limited and All-Stop	All Stop	All Stop
Span of Service	All Day	All day	All Day	All Day	All Day	All Day	All Day
Frequency of Service in Peak Hours (Headway in Minutes)	30	9	12	2-10	10	12	5
Frequency of Service Off-Peak (Head-way in Minutes)	30	30		15-20			
Avg. Station Spacing Distance	0.96	0.29	0.84	0.75	0.57	0.56	About 900 feet

Exhibit 2-27: Experience with BRT Service Plans (cont'd.)

	Phoenix	Pittsburgh			Sacramento	San Jose	Santa Monica	Halifax
	RAPID	East Busway	South Busway	West Busway	EBus	Rapid 522	Lincoln Rapid	MetroLink
Route Structure	Express Routes				Replaced limited service route	Overlaps local route. Headway based.	Overlaps Local Route	Overlaps route
Route Type	Express	All-Stop	All-Stop	All-Stop		Limited	Limited	Express - Stop only at major transit centers
Span of Service	Weekday Peak Hour only	All Day	All Day	All Day	All-day	All Day Mon-Sat	Peak-Hour Only	2 routes all-day weekdays, 1 route peak-hour only
Frequency of Service in Peak Hours (Headway in Minutes)	10	0.58		1.33	15 min	15		10
Frequency of Service Off-Peak (Head-way in Minutes)					20 min	15		30
Avg. Station Spacing Distance	0.25?	1.14	0.54	0.83	0.5 mile	0.85	0.82	3.11

Exhibit 2-27: Experience with BRT Service Plans (cont'd.)

	Ottawa	York	Bogotá	Guayaquil	Pereira	Amsterdam	Caen
	Transitway	VIVA	Transmilenio	Metrovia	Megabus	Zuidtangent	Tram on Wheels
Route Structure	Carries 6 BRT routes and many local routes	BRT network overlaid on existing local routes	Replaced existing privately-operated routes	Replaced existing privately-operated routes	Replaced existing privately-operated routes	New city orbital BRT link with intermodal links	Two routes overlapping in core area providing high frequency in downtown and Y pattern coverage north/ south of downtown
Route Type	BRT routes are all-stop. Local routes operate as all-stop, express, and trunk-feeder	Limited-stop	Trunk-Feeder (all-stop, express along trunk)	Trunk-Feeder (all-stop along trunk)	Trunk-Feeder (all-stop, limited, and express along trunk)	Limited Express	All-Stop
Span of Service	Some routes all day	18 hours per day	All day		All day	All Day	All Day
Frequency of Service in Peak Hours (Headway in Minutes)	2-20	3-15	1 - 3	4 - 6	3 - 5	7.5 - 8	3-6 (where routes overlap)
Frequency of Service Off-Peak (Head-way in Minutes)	4-30	15	10		10	10	10-15
Avg. Station Spacing Distance	0.60 - 1.30	0.7-1.0 (varies by route)	0.80	0.56		0.9-1.2	0.2-0.25

Exhibit 2-27: Experience with BRT Service Plans (cont'd.)

	Edinburgh	Eindhoven	Leeds	London	Rouen	Utrecht	Adelaide
	Fastlink	Phileas - Western Corridor	Superbus	Crawley	TEOR	Busway	North East Busway
Route Structure	Single radial route linking periphery to downtown	Two radial routes overlapping in central area, linking downtown with periphery and airport	Two radial routes linking periphery to downtown	2 north-south overlapping routes. Links downtown to employment areas to north (Gatwick) and south	Three radial routes overlapping in central area, linking downtown with hospital, universities and peripheral areas	Three radial routes linking downtown to periphery	Replaced Local Routes
Route Type	All-Stop	All-Stop	Trunk-Feeder	All-Stop	All-Stop	All-Stop	All stop Express/ Semi Express
Span of Service	All Day	All Day	All Day	All Day	All Day	All Day	Mix Peak Only and All Day
Frequency of Service in Peak Hours (Headway in Minutes)	3	8	2-8	10	3	2-4	1.1
Frequency of Service Off-Peak (Head-way in Minutes)	10	10	2-8	10-20	4	3-7.5	4
Avg. Station Spacing Distance	0.2-0.25	0.34		0.25	0.33	0.9-1.2	3.10

Exhibit 2-27: Experience with BRT Service Plans (cont'd.)

	Brisbane		Sydney T-Ways			Beijing	Hangzhou	Kunmimg
	South East Busway	Inner Northern Busway	Liverpool-Parramatta	North-West Blacktown-Parklea	North-West Parramatta-Rouse Hill	Line 1	Line B1	Busway Network
Route Structure	Overlaid on existing local routes	Replaced Local Routes	Overlaid on existing local routes	Overlaid on existing local routes	Overlaid on existing local routes	Replacing existing routes in busiest corridors	Replacing existing routes in busiest corridors	Center-lane BRT network for existing routes in busiest corridors
Route Type	All Stop and Express, with some express service to CBD with no stops.	All Stop	All Stop	All Stop	All Stop	All-Stop	All-Stop	All-Stop
Span of Service	Mainly All Day	Mix Peak Only and All Day	All Day	All Day	Most All Day	All Day	All Day	All Day
Frequency of Service in Peak Hours (Headway in Minutes)	16 sec headway at Buranda Station	4.6	10.0	8.6	4.0		3 - 4 minutes	
Frequency of Service Off-Peak (Head-way in Minutes)	2	5	15	11.6	5			
Avg. Station Spacing Distance	1.00	0.41	0.54	0.42	0.50		0.41	

BRANDING ELEMENTS

Description

Role of Branding Elements in BRT

Branding involves a wide range of strategies and tactics to package a set of product characteristics and service attributes and to build and reinforce a brand that communicates the distinct characteristics of a product—in this case, a BRT system. A successful BRT brand can communicate the value of a BRT system in both quantifiable service attributes and performance. Successful brands also can reinforce impressions of BRT as a "premium" service, thereby attracting ridership.

Transit agencies typically develop their branding for BRT systems within the context of a larger branding initiative and communications plan. This section details just some of the basic choices available for transit agencies when considering their larger branding strategies. A discussion of the impact of packaging these branding elements with service characteristics is located in the section on Image and Identity—Brand Identity in Chapter 3.

Characteristics of Branding Elements

For BRT system branding, there are at least two major characteristics or elements of branding which transit agencies can consider when developing a BRT system—the market classification of BRT and branding devices:

- ***Marketing Classification of BRT Service***—The marketing classification of BRT describes how BRT fits within the rest of a transit system. This classification reflects both functional differences in service attributes and differences in how the services or systems are marketed.
- ***Branding Devices***—Branding devices or brand identifiers are attributes, usually visual, that customers can associate with a product. In the case of BRT, the most common branding devices are use of separate brand names, logos, and colors or color palettes.

Marketing Classification of BRT

There are at least three marketing classifications for BRT (or ways to characterize BRT services with respect to the rest of an area's transportation network). The first two that are discussed—*BRT Marketed as a Separate Tier of Service* and *BRT Marketed as a Rapid Transit Route* represent active branding strategies. The third—*BRT Marketed with No Differentiation from Other Routes*—represents the default case of doing no special branding.

Marketing Classifications of BRT

BRT as a Separate Tier of Service

With enough features, BRT can be marketed as a separate tier of service, operated independently of local and express bus routes and rapid transit routes. This often involves the use of a special name for the type of service (e.g., "Rapid"), separate colors or logos, and a separate fleet of vehicles.

Signage for EmX

REASONS TO IMPLEMENT

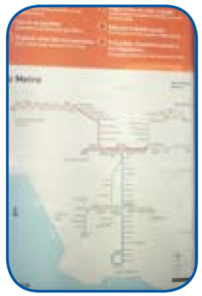
- To differentiate the service from local bus service.

CONSIDERATIONS/ REQUIREMENTS

- Requires integration among transit agencies to achieve the designed brand characteristics of BRT service
- Requires stations and vehicles that emphasize the function and attributes of the service and highlight its distinct nature. At a minimum, a separate shelter type and vehicle livery are employed.

BRT as a Rapid Transit Route

BRT systems with advanced features, especially dedicated running ways, can be classified and marketed as elements of a larger regional rapid transit system. Often, this can take the form of equating BRT systems and lines as equivalent to other forms of rapid transit (light rail, heavy rail, and commuter rail.) This classification of BRT involves the inclusion of BRT routes into regional rapid transit maps and notation and naming of BRT lines in a manner similar to other rapid transit service and distinct from local bus service.



Map of Rapid Transit Routes in Los Angeles

Reasons to implement:

- To highlight the integration of BRT into the regional rapid transit network.
- To raise expectations of performance and service delivery for both transit agency staff and customers, thereby promoting a higher level of customer service and ridership.

Considerations/requirements:

- Requires fuller integration of marketing materials and branding strategy to emphasize similarities to rail and other rapid transit modes.

BRT Marketed with Minimal Differentiation from Other Routes

In some cases, routes that incorporate BRT elements have minimal or no differentiated branding or marketing from regular local or express routes. Services in this category are often noted as limited or express versions of other routes in the system. Often, these routes follow the same route numbering system and look and are served by similar vehicles as regular routes.

Reasons to implement:

- When BRT features are not significant enough to warrant a differentiated branding strategy.

Considerations/requirements:

- Requires no change to marketing and branding strategies.

Branding Devices

Branding devices are tools that transit agencies can use to define and reinforce a special brand for BRT. They are primarily visual in nature, but each plays a role in communicating the characteristics of a BRT system and emphasizing the distinct nature of BRT.

Branding Devices

Brand Name

A brand name, in the form of a word or phrase, can distinguish BRT systems from other transit services available in a given region. Brand names often include the name of the agency operating a particular BRT system. Brand names can be applied to either the services or routes alone, the infrastructure within which BRT services operate, or both.

Rapid (AC Transit)

REASONS TO IMPLEMENT

- Packages all the characteristics of a BRT system into an easily identifiable name.
- Communicates particular characteristics of a BRT system (e.g., "Rapid"), the area it serves, or its relationship to other rapid transit services in a region.

CONSIDERATIONS/ REQUIREMENTS

- The selection of a brand name must show some relationship to names of other services within a broader transportation system.
- Brand names often require cooperation among several departments and business functions within an agency to ensure that the brand conveys a consistent and appropriate meaning to the general public.

Logos

Distinct colors in logos communicate the distinct nature of a specific transit service, in this case, BRT service. A logo is a visual image taking the form of the combination of an ideogram (icon, sign, or emblem) or logotype (written form of the brand name).

REASONS TO IMPLEMENT

- To associate the distinctiveness of a BRT system visually, making the system easy to identify and associate with positive service attributes.

CONSIDERATIONS/ REQUIREMENTS

- Logos often need to have some relationship to an agency's overall visual identity.
- Other visual elements of a BRT system (station shelters, overall station design, and vehicle design and vehicle livery) also need to relate to and incorporate a BRT system's logo and visual communications plan.

Designated Colors

Designated colors distinct for BRT service highlight the distinct nature of BRT service from other services and provide an important reference for passengers.

Color Scheme for LTD's Emerald Express (EmX)

REASONS TO IMPLEMENT

- To add another layer of visual distinction to a BRT system.
- To enable communication of service attributes in a way that transcends language barriers.

CONSIDERATIONS/ REQUIREMENTS

- Like logos, the consistent use of color to designate a BRT brand needs to have some relationship to an agency's overall visual identity.
- Other visual elements of a BRT system (station shelters, overall station design, and vehicle design and vehicle livery) also need to relate to and incorporate a BRT system's logo and visual communications plan.

Other Branding Devices

Other branding devices commonly used for other types of products can theoretically be used for BRT, such as slogans or mottos, mascots, graphic design programs and typefaces, and sound logos. These, however, are used less systematically and tend to be less central to BRT system branding efforts.

REASONS TO IMPLEMENT

- To add another layer of visual or other cues to distinguish a BRT system.

CONSIDERATIONS/ REQUIREMENTS

- Like logos and colors, use of other branding devices needs to have some relationship to an agency's overall communications program.

Effects of Branding Elements on System Performance and System Benefits

Exhibits 2-28 and 2-29 summarize the links between station elements and the BRT performance indicators and system benefits identified in Chapter 1. These links are explored further in Chapters 3 and 4.

Exhibit 2-28: Summary of Effects of Station Elements on System Performance

	System Performance					
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity	Accessibility
Marketing Classification • BRT Marketed with No Differentiation from Other Routes • BRT Marketed as a Separate Tier of Service • BRT Marketed as a Rapid Transit Route	Minimal impact	Minimal impact	Classifying BRT as a separate Tier of Service or as a Rapid Transit Route builds and reinforces Brand Identity	Minimal impact	Minimal impact	Minimal impact
Branding Devices • Brand Name • Logo • Designated Color • Other Branding Devices	Minimal impact	Minimal impact	Use of branding devices such as brand names, logos, color schemes accentuates brand identity and contributes to comprehensive contextual design of BRT systems	Minimal impact	Minimal impact	Minimal impact

Exhibit 2-29: Summary of Effects of Station Elements on System Benefits

	System Performance				
	Higher Ridership	Capital Cost Effectiveness	Operating Cost Efficiency	Transit-Supportive Land Development	Environmental Quality
Marketing Classification • BRT Marketed with No Differentiation from Other Routes • BRT Marketed as a Separate Tier of Service • BRT Marketed as a Rapid Transit Route	By enhancing brand identity, marketing BRT as either a separate tier of service or as integrated with a region's rapid transit system can highlight higher performance of BRT and attract higher ridership.	Minimal impact	Minimal impact	Minimal impact	Minimal impact
Branding Devices • Brand Name • Logo • Designated Color • Other Branding Devices	By enhancing brand identity, different branding devices can highlight higher performance of BRT and attract higher ridership.	Minimal impact	Minimal impact	Minimal impact	Minimal impact

Implementation Issues

The flexible and diverse nature of BRT presents unique issues and challenges related to implementation of branding elements.

Implementation Issues During Project Development

Brand Strategy

During planning and project development, it is important to implement branding elements in the context of developing a comprehensive brand strategy. As one initial activity in developing a brand strategy, it is important to discern the value of the brand of the existing services that a transit agency already operates. Developing a BRT system provides an opportunity to articulate a brand for a unique and distinct system. Because markets are particular to specific regions and evolve over time, the approach to BRT must be tailored to each specific situation.

Building a brand strategy follows three key steps:

Market Research and Business Process Review—Research is important to understand the target audience. This usually involves activities such as surveys, focus groups, and interviews with both users and non-users of transit service. Consumer research reveals demographic information of the market area and what potential consumers perceive about existing transit service and what they would value in a new transit service. Research can also involve an exploration internal to the implementing agency to gauge internal attitudes about provision of service and how business processes affect the end product.

Identification of Points of Differentiation for BRT—The second step in developing the brand involves identifying what the point of differentiation is for BRT. This step involves an exploration of what features are relevant to the target audience. These features can be both related to what the product does (its performance—travel time savings, reliability, safety, security, and effective design) and the impression it conveys. These points of differentiation will help in the planning for the system and selection of elements and ultimately with the marketing of the service.

Implementation of the Brand—Implementation of the brand involves more than just implementing brand elements alone. More broadly, it involves at least three activities:

- Implementation of a package of BRT System Elements—The elements that most support the brand and its message are key to presenting an attractive product that potential customers respond to.
- Changing internal business processes—Critical to a successful product is an organization that believes in the product it is presenting to the customer and delivers the product efficiently and effectively. This often involves reorganization of internal business structures, processes, relationships, and delivery approaches.
- Implementing branding and communication plan—As the internal business processes are settled, a branding and communication plan should be developed and executed.

Implementation Issues During Operation

Continued Brand Management

Sustaining the brand of a BRT system and its perception as a "premium" transit product requires constant attention. The steps necessary for successful launch—market research, review of the BRT product and its value, and marketing—are required to be repeated and refreshed regularly and periodically.

INTEGRATION OF BRT ELEMENTS INTO BRT SYSTEMS

Introduction

BRT system elements must be packaged in an integrated fashion to best achieve the goal of a fast, reliable, and attractive system. The previous sections have described the numerous individual BRT system elements and characteristics. The integration of some packages or groups of disparate elements can yield more total benefits than the sum of the benefits of the individual parts. Special attention is required to optimally integrate these packages of elements.

This section explores five different interfaces that represent packages of BRT elements:

- Boarding Level Interface
- Boarding Capacity Interface

- Route Network Operations Interface
- Intersection Operation Interface
- Integrated Communication System Interface

Interfaces for BRT Element Integration

Successful implementation of BRT elements requires that elements function seamlessly with other elements. This section presents various combinations of elements and the planning and design issues associated with successful integration of each set of elements to support BRT system performance and maximize BRT benefits.

Boarding Level Interface

The boarding level interface involves primarily vehicles and stations. Properly designed together, vehicles and station platforms can contribute to level boarding or near-level boarding.

Level boarding eliminates both vertical and horizontal gaps between vehicle floor and station platforms, thereby eliminating the need to take time to deploy ramps for wheelchairs or mobility devices and allowing instant boarding for all passengers. Level boarding, therefore, significantly expedites the speed of boarding and alighting processes thereby reducing travel time and improving customer response. Level boarding can be achieved through effective integration of low-floor vehicles, level station platforms (generally at least 14 inches), and precision docking (either through mechanically guided running ways or ITS guidance [Vehicle Infrastructure Integration]). In many international cases, level boarding is achieved with high-floor vehicles, high platforms, and drop ramps at stations.

Near-level boarding can be achieved through a combination of low-floor vehicles and raised station platform heights. While not as significant as true level boarding, near-level boarding can still reduce (if not eliminate) the rate of ramp deployment and facilitate boarding for all passengers.

Boarding Capacity Interface

The boarding capacity interface involves a set of elements that facilitates the broader boarding and alighting process. Boarding through multiple doors allows BRT systems to process passengers at a rate similar to rapid transit systems, reducing the impact of high passenger volumes on dwell times. This interface involves integration of vehicles with multiple door channels (multiple doors and multiple door streams), off-board fare collection (either barrier-separated or proof-of-payment fare collection) or on-board fare collection enhanced with electronic fare media. Multiple-door boarding is also facilitated by a combination of running ways and stations designed to allow quick processing of vehicles in and out of stations (e.g., stations that allow passing of vehicles, stations with multiple berths, and dedicated running ways).

Route Network Operations Interface

The combination of running way and station elements helps determine the types of service designs that can be operated. Integrated network operations generally require a combination of more exclusive running ways (on-street dedicated running ways or off-street types), stations with passing lanes and extended platforms, and a common vehicle fleet. Generally, there are also transit centers located at major terminals to facilitate transfers among feeders to the trunk-line BRT routes. The higher the level of exclusivity and grade separation of the running way, the higher the number of routes that can be operated in an integrated fashion with the BRT system. Features that introduce delay, such as at intersections, limited-capacity stations, and other bottlenecks along the running way, limit the capacity of the system and, therefore, number of routes that can be integrated into the BRT network.

Intersection Operations Interface

Efficient operation of BRT routes through intersections requires integration of running way design and ITS with some contributions from station design and vehicles. The basic integration of BRT at intersections begins with Transit Signal Priority systems (and other traffic priority systems) and running way designs (lane configurations) that allow for physical or electronic queue jumpers. This requires some integration with the communication systems on the vehicle and the implementation of other ITS elements (an Automatic Vehicle Location system and an advanced communication system). Placing stations on the far-side of intersections also facilitates the passage of BRT vehicles through intersections.

Integrated Communication Systems Interface

As mentioned in the ITS section, the effectiveness of ITS and other electronic components requires effective integration of the communications systems. This involves almost all ITS components: all communications equipment on vehicles (transit signal priority transponders, collision warning devices and other assist and automation technologies, advanced communication systems, Automatic Vehicle Location, on-vehicle variable message signs, and passenger counters), electronic fare collection equipment (either on vehicles or at stations), and any communications systems associated with the running way (guidance) and stations (passenger information systems). The extent to which all these elements are integrated affects whether the functional abilities of each individual system are realized. For example, an Electronic Fare Collection system may be linked to an AVL/GPS system to provide data on the boarding profile along a BRT route. A system to archive and process the data would support operations and planning. Most important, the integration of the elements with an advanced communication system enhances the ability to respond and transmit information in real time, making the system more responsive to customers.

BRT ELEMENTS AND SYSTEM PERFORMANCE

This chapter identifies six key BRT system performance attributes—travel time, reliability, image and identity, passenger safety and security, system capacity, and accessibility. These six ways that BRT systems perform better also represent ways that transit passengers benefit from the implementation of BRT. The section on each performance attribute includes a description of the attribute, an overview of how individual BRT elements may contribute to performance, and a review of the performance of existing systems. This review includes a research summary (in cases where applications in transit demonstrate effects on performance) and system performance profiles (short case studies of BRT and non-BRT applications). Finally, the discussion of each performance attribute describes the indicators used to measure the performance attribute and a summary of the performance associated with BRT systems in cities around the world that have provided relevant data. The summary allows for a comparison of different approaches undertaken by transit agencies and different performance results across systems.

The following six BRT system performance attributes are discussed in this chapter:

- **Travel Time** represents a primary performance attribute of BRT systems—the ability to transport passengers on their respective trips quickly. The impact of BRT systems on travel time savings depends on how each BRT element is implemented in a specific application and how they relate to each other and the other elements of the BRT system. There are several different travel time components that BRT systems impact, including:

  Running time—the time BRT vehicles and passengers actually spend moving. Running times are dependent on traffic congestion, delays at intersections, and the need to decelerate into and accelerate from stations.

Station dwell time - the time vehicles and passengers spend at stations while the vehicle is stopped to board and alight passengers.

Waiting and transfer time - the amount of time passengers spend waiting for the first transit vehicle and the amount of time they spend waiting for subsequent services required to complete their trip.

- **Reliability** represents the variability of travel times. Reliability is affected by many BRT features. The three main aspects of reliability include:

  Running time reliability - the ability to maintain consistent travel times.

  Station dwell time reliability - the ability for patrons to board and alight within a set timeframe, with varying loads of passengers at stations, especially as measured across varying levels of congestion at different periods of a service day and on vehicles, thereby minimizing delay at stations.

  Service reliability - the availability of consistent service (availability of service to patrons, ability to recover from disruptions, availability of resources to consistently provide the scheduled level of service).

- **Identity and image** capture how a BRT system is perceived by both passengers and non-passengers. These attributes reflect the effectiveness of a BRT system's design in positioning it in the transportation marketplace and in fitting within the context of the urban environment. It is important both as a promotional and marketing tool for transit patrons and for providing information to non-frequent users as to the location of BRT system access points (i.e., stops and stations) and routing. Two major elements of BRT system identity and image capture its identity as a product (brand identity) and as an element of the urban form (contextual design):

  Brand identity - reflects how the BRT system is positioned relative to the rest of the transit system and other travel options. Effective design and integration of BRT elements reinforce a positive and attractive brand identity that motivates potential customers and makes it easier for them to use the system.

  Contextual design - measures how effectively the design of the BRT system is integrated with the surrounding urban environment.

- **Safety and security** for transit customers and the general public can be improved with the implementation of BRT systems, where safety and security are defined as:

  Safety - freedom from hazards, as demonstrated by reduced accident rates, injuries, and improved public perception of safety.

  Security - the actual and perceived freedom from criminal activities and potential threats against customers and property.

- **Capacity** is defined as the maximum number of passengers that can be carried past a point in a given direction during a given period along the critical section of a given BRT under specific operating conditions. Virtually all BRT elements affect capacity.

- **Accessibility** describes the general availability of service to all transit users or proximity to points of access (stations and stops) of the transit system. This document describes accessibility in a more specific sense—the ability and ease with which individuals with disabilities can use the transit system.

TRAVEL TIME

Travel time represents the amount of time spent by passengers (and vehicles) from the beginning to the end of their trips. Travel time may be the single attribute of a transit system that customers care about the most and isparticularly important for non-discretionary, recurring trips such as those made for work purposes. Relatively high BRT running speeds and reduced station dwell times make BRT services more attractive for all types of customers, especially riders with other transportation choices. Waiting and transfer times have a particularly important effect, and BRT service plans generally feature frequent, all–day, direct service to minimize them. Travel times vary across different operating conditions.

"Operational Analysis of Bus Lanes on Arterials" indicates that, for suburban bus operations, the majority of overall bus travel time (about 70 percent) takes place while the bus is in motion. For city bus operations, particularly within Central Business Districts (CBDs), a lower percentage of overall bus travel time (about 40-60%) takes place while the bus is in motion. This is due to heavier passenger boarding and alighting volumes per stop, higher stop density, more frequent signalized intersections, more pedestrian interference and worse traffic conditions.

This report, considers four travel time components:

- **Running time**—time spent in the vehicle traveling from station to station
- **Dwell time**—time spent in the vehicle stopped at a station
- **Wait time**—time spent by passengers initially waiting to board a transit service
- **Transfer time**—time spent by passengers transferring between BRT service and other types of transit service

Each component of travel time is described in further detail with a discussion of how BRT elements contribute to their reduction. (One aspect of travel time often mentioned in transportation planning is called access time—the time spent by passengers walking or taking another non-transit mode to reach a particular transit service. It is not discussed here since it is affected by the intensity and location of land uses.)

It is important to note that savings to travel time are experienced by both vehicles and passengers. While this discussion focuses on travel time savings across an entire route, for consistency of reporting across systems, it is important to note that passengers will experience travel time savings on BRT systems depending on their individual trip lengths.

Running Time

Description of Running Time

Running time is the element of travel time that represents the time spent by BRT passengers and vehicles moving between stations. In most cases, the maximum speed of the vehicle itself is not usually a determining factor for running travel times. Vehicles in service in dense corridors rarely accelerate to the maximum speed of the vehicle since their speeds are limited by general traffic speeds and close stop spacing. The major determining factors of running time are the delays that the vehicle encounters along the way, including congestion due to other vehicle traffic, delays at traffic signals to accommodate cross-traffic and pedestrians, delays to make turns, the number of stations a vehicle is required to serve, and the design of the BRT route structure.

Effects of BRT Elements on Running Time

The primary BRT elements that improve travel times relative to conventional bus service are described below.

Right-of-Way Locations, Level of Running Way Priority
Right-of-way locations and level of running way priority are two of the key BRT elements that affect travel times. In general, BRT systems in off-street rights-of-way have faster speeds or shorter travel times for equivalent distances. The impacts of each of the on-street and off-street running way types are described for each level of running way priority.
On-Street Running Way Types
Mixed-flow lanes—BRT vehicles operating in mixed-flow lanes are typically constrained by the speed of general traffic. This represents the basic condition of bus operation upon which other levels of running way priority can provide improvements.
Mixed-flow lanes with queue jumpers—Queue jumpers allow vehicles to bypass traffic queues (i.e., traffic backups) at signalized locations or bottlenecks. Queue jumpers often are used in combination with transit signal priority.
On-street bus lanes reduce delays associated with congestion in city streets. Dedicated lanes often are used in conjunction with transit signal priority to minimize unpredictable delays at intersections.
Bus-only streets provide similar reductions in delay as on-street bus lanes with the added benefit of removing delays resulting from conflicts with automobiles changing lanes across the BRT running way. When implemented along a street with significant pedestrian activity (e.g. a shopping district), bus speeds are often limited.
Off-Street Running Way Types
Expressway bus lanes, similar to grade-separated exclusive transitways, eliminate most potential delay within an expressway/freeway environment. Typically, they have joint operation with other vehicles as high-occupancy vehicle (HOV) lanes and therefore may experience some delay due to congestion.
At-grade exclusive transitways eliminate the hazards due to merging or turning traffic or pedestrians and bicyclists crossing into the middle of the running way, allowing BRT vehicles to travel safely at higher speeds.
Grade-separated exclusive transitways eliminate all potential delay, including delays at intersections. BRT vehicles are free to travel safely at relatively high speeds from station to station.
Stations—Station Location
Off-street, off-line stations divert BRT vehicles from the main BRT running way and thus create delay associated with turns and access to and from the transit running way and within a transit center. On-line station types (either on-street or off-street) create no such delay.

Stations—Passing Capability
Stations that allow for passing minimize delays at stations, especially if the service plan includes high-frequency operation or multiple routes. Passing capability also allows for the service plan to incorporate route options such as skip-stop or express routes, which offer even lower travel times than routes that serve all stations.
ITS—Transit Vehicle Prioritization
Transit signal priority (TSP), enables the BRT vehicle to travel faster along the roadway through increased green time. TSP is especially useful for travel time savings if implemented at key intersections that cause the highest delay.
Signal timing/phasing optimization can provide similar benefits, but perhaps to a lesser extent. Retiming or coordinating signals along a corridor is generally directed at improving all traffic flow.
Station and lane access control can reduce the amount of time a BRT vehicle sits in a queue waiting to enter a dedicated BRT or HOV lane or station.
ITS—Intelligent Vehicle Systems
For those BRT systems operating on narrow roadway ROW (e.g., shoulders), **lane-keeping assistance systems** (or vehicle guidance systems) allow the BRT vehicle operator to travel at higher speeds than otherwise would be possible due to the physical constraints of the ROW.
Precision docking enables a BRT vehicle to quickly dock at a BRT station and reduce both running travel time and station dwell time. Docking technology removes the burden on the BRT vehicle operator of steering the vehicle to within a certain lateral distance from the station platform, allowing for faster approaches to stations.
Service and Operations Plan—Route Type
Reducing the number of station stops by offering limited-stop or express service can reduce delays associated with decelerating and accelerating out of the station and with station loading.
Service and Operations Plan—Station Spacing
Increasing station spacing by reducing the number of stations reduces delay associated with decelerating into and accelerating out of the station and with loading at the station. Cumulatively, the travel time savings associated with widening the station spacing can be significant.
Service and Operations Plan—Schedule Control Method
When frequencies are high enough, encouraging vehicle operators to travel the route as fast as they can and managing on-time performance through **headway-based schedule control** can encourage vehicles to travel at the maximum speeds that are possible between stations.

Performance of Existing Systems

Transit agencies have significant experience in achieving travel time savings and increasing the speed of service through deployment of BRT elements. This section characterizes this experience in three sections: a summary of relevant research on travel time savings strategies, profiles of noteworthy experience (including both BRT and non-BRT cases), and a summary of BRT system characteristics that affect running time and available performance data.

Research Summary

Research in transit operations suggests how running times can be reduced through many elements that are incorporated into BRT. The *Transit Capacity and Quality of Service Manual, 2nd Edition* provides estimated average speeds of buses, as a function of three variables:

- type of running way (e.g., busway or freeway HOV lane, arterial street bus lane, or mixed traffic)
- average stop spacing
- average dwell time per stop

Exhibit 3-1 makes clear that the use of off-street ROW locations with wide station spacing (such as expressway bus lanes or grade-separated transitways) is the most effective way to increase bus travel speeds. All things (e.g., station spacing, fare collection approach, etc.) being equal, BRT revenue speeds on exclusive running ways will compare favorably with most heavy rail and exclusive right-of-way light rail systems.

Exhibit 3-1: Estimated Average Bus Speeds on Busways or Exclusive Freeway HOV Lanes

Average Stop Spacing (mi)	Average Dwell Time per Stop (secs)				
	0	15	30	45	60
0.5	36 mph	26 mph	21 mph	18 mph	16 mph
1.0	42 mph	34 mph	30 mph	27 mph	24 mph
1.5	44 mph	38 mph	35 mph	32 mph	29 mph
2.0	46 mph	41 mph	37 mph	35 mph	32 mph
2.5	46 mph	42 mph	39 mph	37 mph	35 mph

Note: Assumes 50 mph top running speed of bus in lane
Source: Transit Capacity and Quality of Service Manual, 2nd Edition, p. 4-46.

As shown in Exhibit 3-2, having dedicated bus lanes on arterial streets (also known as on-street bus lanes) provides for speeds that are similar to that of street-running light rail systems.

Exhibit 3-2: Estimated Average Bus Speeds on Dedicated Arterial Street Bus Lanes

Average Stop Spacing (mi)	Average Dwell Time per Stop (secs)					
	10	20	30	40	50	60
0.10	9 mph	7 mph	6 mph	5 mph	4 mph	4 mph
0.20	16 mph	13 mph	11 mph	10 mph	9 mph	8 mph
0.25	18 mph	15 mph	13 mph	11 mph	10 mph	9 mph
0.50	25 mph	22 mph	20 mph	18 mph	16 mph	15 mph

Source: Transit Capacity and Quality of Service Manual, 2nd Edition, p. 4-53.

Exhibit 3-3 indicates that in typical mixed traffic conditions, bus speeds are significantly lower than those for BRT, light and heavy rail systems operating on exclusive running ways. This is due to the traffic itself, as well as the time required for the bus to exit / re-enter the traffic stream at each stop.

Exhibit 3-3: Estimated Average Bus Speeds in General Purpose Traffic Lanes

Average Stop Spacing (mi)	Average Dwell Time per Stop (secs)					
	10	20	30	40	50	60
0.10	6 mph	5 mph	5 mph	4 mph	4 mph	3 mph
0.20	9 mph	8 mph	7 mph	6 mph	6 mph	5 mph
0.25	10 mph	9 mph	8 mph	7 mph	7 mph	6 mph
0.50	11 mph	10 mph	10 mph	9 mph	9 mph	8 mph

Source: Transit Capacity and Quality of Service Manual, 2nd Edition, p. 4-53.

Exhibits 3-1 to 3-3 also indicate that stop spacing and dwell times are also significant in influencing average bus travel speeds.

BRT systems improve travel times over conventional bus services through a combination of dedicated running ways, longer station spacing, reduced dwell times at stops (e.g., due to multiple door boarding) and/or ITS applications (e.g., traffic signal priority). BRT experience in the United States suggests that travel time savings is on the order of 25 to 50 percent for recently-implemented BRT systems (*Bus Rapid Transit: Case Studies in Bus Rapid Transit*, p. 51). Findings from 11 international systems in Canada, Brazil, Ecuador, England, and Japan found that speed improvements associated with BRT implementation ranged from 22 to 120 percent (*Bus Rapid Transit—An Overview*). Exhibit 3-4 shows BRT speeds related to the spacing of stations.

Exhibit 3-4: Busway and Freeway Bus Lane Speeds as a Function of Station Spacing

Station Spacing (mi)	Stops Per Mile	Speeds (mph)	
		20-Second Dwell	30-Second Dwell
0.25	4.0	18	16
0.50	2.0	25	22
1.00	1.0	34	31
1.50	0.7	42	38
2.00	0.5	44	40

Source: "Bus Rapid Transit—Implementation Guidelines"

When determining station spacing, there is a tradeoff between patron accessibility and service speed.

System Performance Profiles

Many systems combine BRT elements to achieve travel time savings. The following examples demonstrate that these savings can be achieved with relatively simple improvements such as increased station spacing and with more significant infrastructure investments such as grade-separated running ways.

Metro Rapid, Los Angeles

The Metro Rapid system demonstrates how a combination of increased station spacing, TSP, and queue jumpers can clearly impact travel time. Metro Rapid is a 229-mile network of rapid bus lines that serve greater Los Angeles. The network is overlaid on local bus routes and operates in mixed traffic with TSP, queue jumpers, and fewer stops implemented to improve speeds over the local service. Overall, the Metro Rapid lines provide an average 25 percent time savings over local service. An evaluation of the Wilshire/Whittier Boulevard BRT line found that average travel time savings during peak periods was 28 percent compared to previous bus service. The TSP system contributed to 27 percent of the overall travel time savings; the remaining 73 percent was due to BRT elements such as station spacing and location. The Ventura Boulevard BRT line saw similar results, with a 23 percent overall travel time reduction and TSP contributing to 33 percent of the travel time savings. Metro continues to add Metro Rapid lines, and now has implemented a 450-mile network of around 30 lines.

East, South, and West Busways, Pittsburgh

The East Busway and South Busway in Pittsburgh each provide a fully grade-separated transitway for vehicles traveling between downtown Pittsburgh and suburbs to the east and south. With the introduction of the East Busway, several routes that had served the corridor were diverted to the busway to take advantage of the faster speeds and reliability on the busway. Along with the diversion of these routes to the busway, the downtown circulation segments of the routes also were realigned. The time required for walk access to service, downtown circulation, and line-haul travel was calculated for six key downtown destinations for both the AM and PM peaks. In all cases in the AM peak, the line-haul travel time decreased by an average of 5 or 6 minutes, while downtown circulation time decreased for four out of six locations. Overall, total travel time has decreased by 52 percent. The South Busway has demonstrated even higher reductions of 55 percent. The West Busway operates on an at-grade busway and has demonstrated somewhat lower travel time savings of 25 percent (Pultz and Koffman 1987).

HealthLine BRT, Cleveland

The Greater Cleveland Regional Transit Authority (RTA) has implemented a 7.1-mile BRT corridor along the city's main east-west thoroughfare, Euclid Avenue. The service, named the HealthLine, features multiple BRT elements designed to improve travel times, including an exclusive two-lane median busway in the corridor's Midtown section, exclusive curbside lanes for 2.3 miles, transit signal priority, level boarding, off-board fare collection, and articulated buses with multiple-door entry on both the right and left sides. As of mid-2008, RTA had completed the median busway portion of the route and began operating its conventional 40-ft buses in the busway. Even though the entire service was not yet operational, RTA was already reporting a 26 percent improvement in travel times along this corridor.

Chicago Transit Authority's Express Bus Service

In 1998, the Chicago Transit Authority (CTA) began implementing express bus service overlaid onto its local routes in high ridership corridors. The program seeks to improve travel times by reducing the number of stops by about 75 percent. Express buses stop only at major intersections and for connections to other transit service. The buses stop at basic bus stops with special red "express service" markings. Three initial lines—Western Express, Irving Park Express, and Garfield Express—reported travel time improvements of 15 percent, 25 percent, and 20 percent, respectively. Following the success of these lines, CTA began implementing more express service and, as of 2008, there were 10 express bus routes. CTA may begin implementing signal priority at a later date. The agency has launched web-based real-time bus tracking for many of its bus lines (express and local) and is implementing an effort to reduce bus bunching across its bus service.

BRT Elements by System and Running Time

Multiple performance indicators measure travel time performance, as described below. It should be noted that it is difficult to measure running time separately from dwell times, so these travel time statistics typically include both attributes, aggregated as "end-to-end travel time." Exhibit 3-5 summarizes the travel time savings performance benefits associated with the introduction of BRT systems in 35 cities around the world, based on the following indicators:

- Maximum Peak Hour End-to-End Travel Time—the maximum travel time required to complete a one-way trip from the beginning to the end of the line during weekday peak hours.
- Uncongested End-to-End Travel Time—the average travel time required to complete a one-way trip from the beginning to the end of the line during weekday non-peak hours of service.

- ✧ Average Speed in Peak Hour (mph)—determined by dividing the total one-way route length by the maximum peak-hour end-to-end travel time, multiplied by 60.
- ✧ Average Uncongested Speed (mph) - determined by dividing the total one-way route length by the uncongested end-to-end travel time, multiplied by 60.
- ✧ Percent Travel Time Change in Corridor Before vs. After BRT—derived by calculating the percentage difference in travel time at peak hours between the BRT service and the transit travel in this corridor prior to implementation of BRT. This is one way of measuring the travel time benefits of BRT; however, not all agencies have calculations for pre-BRT corridor travel times available. The alternative measure is below.
- ✧ Percent Travel Time Change in Corridor BRT vs. Local Bus in Same Corridor—derived by calculating the percentage difference in travel time at peak hours between a BRT line and a local line that operate along the same alignment and have the same end points. This is not applicable for agencies that have replaced local bus service in the corridor.
- ✧ Survey of Customer Travel Times—indicates the actual travel time savings reported by customers through rider surveys. Only a few agencies have provided results of such surveys.

The data shown in Exhibit 3-5 provide empirical context for assessing the impact of BRT elements on transit running times across a broad array of BRT strategies that encompass a range of BRT treatments. Some cities operate multiple BRT corridors or routes; if the treatments or performance results are substantially different, they are listed separately. In all, there are 54 different BRT systems or lines analyzed in the table.

Most of the systems described in the table operate in an on-street environment, either in mixed-flow lanes or exclusive curbside or median lanes. Roughly one-third feature off-street running way operation. Approximately half feature prioritization elements such as queue jumping and transit signal priority.

Overall, the BRT systems showed improvements in travel time over previous corridor travel times or existing local bus service. Reported travel time improvements range from 5 to 70 percent, with half of the systems demonstrating improvements between 20 and 40 percent. The median percentage improvement was 25 percent.

According to the data, the strongest indicator of improved travel time is the level of running way segregation. Almost all of the systems with less than 25 percent improvement operate on-street in mixed traffic lanes. The systems with the highest reported travel time savings of 40 percent or higher were those with grade-separated busways—Adelaide, Brisbane, Pittsburgh, and Edinburgh (Edinburgh reports the time savings only for the exclusive guideway portion of its BRT corridor). However, this correlation is not absolute. For example, the Orange Line BRT in Los Angeles reports a 16 percent improvement in travel time despite operating in a segregated right-of-way. This is the result of safety concerns at the running way's at-grade intersection crossings, which require drivers to slow down significantly when passing through an intersection. Indeed, the issue of at-grade crossings would appear to be a trend in the data, as both Miami and the Pittsburgh West Busway, which also include some at-grade intersections, have lower time savings than the busways with total grade separation (Pittsburgh's East and South busways, Brisbane, and Adelaide). Segregation offers a comparative benefit over non-segregated BRT, but all of the BRT systems reported improvements over previous or current local service.

Transit signal priority is a feature on many of the lines that showed improvement, suggesting that it likely contributes to the improvement over local service. The data did not, however, reveal an obvious correlation between higher travel time savings and use of transit signal priority.

The data also reveal the importance of certain service design features such as longer station spacing and limited-stop or express service in reducing running travel times. In addition to prevailing traffic conditions, maximum transit vehicle speeds are limited by the distance between stations. The desire to maximize overall service speeds is part of the rationale behind limited service, which designates fewer stops along a given distance than traditional local service. Local bus service typically features stop spacing of 0.2 or 0.25 miles. By contrast, almost all of the BRT systems shown here have an average station spacing of 0.5 miles or more, with the on-street systems typically between 0.5 and 1 mile and the segregated busway systems at 1 mile or longer.

For BRT systems sharing lane space with local buses on mixed-flow lanes, designing a limited-stop service can reduce end-to-end travel time, especially when complemented with TSP capabilities. Perhaps the best example of this is the Metro Rapid service in Los Angeles, which, as described earlier, reduces travel time an average of 25 percent over local lines operating on the same alignment.

Another example is the Metrolink system in Halifax, which offers express service with extremely long station spacing, an average of 3.3 miles. This allows the system to achieve travel time savings of 33 percent, comparable to some of the segregated ROW BRTs.

Finally, the data seem to indicate a strong correlation between passing ability at stations or bus pullouts and improved travel time. However, since most of the systems with this feature operate on segregated busways, it seems likely that the immediate cause of the performance improvement is the running way itself.

Exhibit 3-5: BRT Elements by System and Travel Time

	Albuquerque	Boston Silver Line		
	Rapid Ride	Washington Street	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Running Way (mi)				
On-Street Mixed Lanes	13.1	0.2	3.5	1.2
On-Street Exclusive Bus Lanes	0.7	2.2		
Off-Street Mixed Lanes				
Off-Street Reserved Lanes				
At-Grade Transitways				
Grade-Separated Transitways			1.0	1.0
Queue Jumpers				
Station				
Location	On-street	On-street	On- and off-street	On- and off-street
Passing Capability	No	No	No	No
ITS				
Transit Vehicle Prioritization	TSP	TSP		
Intelligent Vehicle Systems				
Service Plan				
Route Type	Limited-stop	All-stop	All-stop	All-stop
Average Station Spacing (mi)	0.87	0.22	0.56	0.22
Method of Schedule Control		Schedule	Schedule	Schedule
Performance				
Maximum (Peak Hour) End-to-End Travel Time (min)	37	18	40	24
Uncongested End-to-End Travel Time (min)	37	12	n/a	n/a
Average Speed in Peak Hour (mph)	17.4	8.0	12.4	
Average Uncongested Speed (mph)	17.4	12.0		
% Travel Time Reduction in Corridor Before vs. After BRT	15%	9%		
% Travel Time Reduction in Corridor Compared to Local Bus		9%		
Survey of Customer Travel Times	77% positive	Yes	78% good or excellent	78% good or excellent

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Chicago			Cleveland
	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Running Way (mi)				
On-Street Mixed Lanes	18.3	9.0	9.4	2.7
On-Street Exclusive Bus Lanes				4.4
Off-Street Mixed Lanes				
Off-Street Reserved Lanes				
At-Grade Transitways				
Grade-Separated Transitways				
Queue Jumpers				
Station				
Location	On-street	On-street	On-street	On-street
Passing Capability	No	No	No	No
ITS				
Transit Vehicle Prioritization				TSP
Intelligent Vehicle Systems				Precision docking
Service Plan				
Route Type	Limited	Limited	Limited	All-stop
Average Station Spacing (mi)	0.47	0.50	0.56	0.42
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule
Performance	2004 data	2004 data	2004 data	
Maximum (Peak Hour) End-to-End Travel Time (min)	92	55	59	34
Uncongested End-to-End Travel Time (min)	60	37	31	
Average Speed in Peak Hour (mph)	11.9	10.3	9.1	
Average Uncongested Speed (mph)	18.3	15.3	17.4	
% Travel Time Reduction in Corridor Before vs. After BRT				26%
% Travel Time Reduction in Corridor Compared to Local Bus	15%	20%	25%	
Survey of Customer Travel Times				

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Eugene	Honolulu	Honolulu	Honolulu	Kansas City
	EmX	City Express A	City Express B	County Express C	MAX
Running Way (mi)					
On-Street Mixed Lanes	1.4	19.0	8.0	18	6
On-Street Exclusive Bus Lanes	2.6				Some segments at certain times of day
Off-Street Mixed Lanes				3.5	
Off-Street Reserved Lanes				17.5	
At-Grade Transitways					
Grade-Separated Transitways					
Queue Jumpers	Yes	No			
Station					
Location	On-street	On-street	On-street	On-street	On-street
Passing Capability					
ITS					
Transit Vehicle Prioritization	TSP				TSP
Intelligent Vehicle Systems					
Service Plan					
Route Type	All-Stop	Limited	Limited-stop	Express	
Average Station Spacing (mi)	0.44	0.56	0.29	0.98	0.30
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule
Performance					
Maximum (Peak Hour) End-to-End Travel Time (min)	30.0	85	53	105	
Uncongested End-to-End Travel Time (min)	18	37	31		
Average Speed in Peak Hour (mph)		10.3	9.1		
Average Uncongested Speed (mph)	13.5	75	40	85	
% Travel Time Reduction in Corridor Before vs. After BRT	8.0	13.4	9.1	22.3	20.0
% Travel Time Reduction in Corridor Compared to Local Bus		20%	25%		
Survey of Customer Travel Times	17.8	15.2	12.0	27.5	

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Las Vegas	Los Angeles	Los Angeles
	North Las Vegas MAX	Orange Line	Metro Rapid (All Routes)
Running Way (mi)			
On-Street Mixed Lanes	2.9	1.0	229
On-Street Exclusive Bus Lanes	4.7		
Off-Street Mixed Lanes			
Off-Street Reserved Lanes			
At-Grade Transitways		13.5	
Grade-Separated Transitways			
Queue Jumpers			
Station			
Location	On-street	Off-street	On-street
Passing Capability		Passing lane at each in-line station	No
ITS			
Transit Vehicle Prioritization	TSP		TSP
Intelligent Vehicle Systems	Precision docking		
Service Plan			
Route Type	Limited-stop	All-stop	Limited
Average Station Spacing (mi)	0.75	1.12	0.71
Method of Schedule Control	Headway	Some headway	Headway
Performance			
Maximum (Peak Hour) End-to-End Travel Time (min)	20	42	Varies by corridor
Uncongested End-to-End Travel Time (min)	17	37	Varies by corridor
Average Speed in Peak Hour (mph)	22.5	20 mph	14 to 16 mph (avg for all routes)
Average Uncongested Speed (mph)	26.5	23 mph	16 - 22 mph (avg for all routes)
% Travel Time Reduction in Corridor Before vs. After BRT		16%	
% Travel Time Reduction in Corridor Compared to Local Bus	25%		Overall avg of 25% faster than local bus routes
Survey of Customer Travel Times	Yes	Very favorable	Very favorable

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Miami	Oakland	Orlando
	Busway	Rapid San Pablo Corridor	LYMMO
Running Way (mi)			
On-Street Mixed Lanes		14.0	
On-Street Exclusive Bus Lanes			
Off-Street Mixed Lanes			
Off-Street Reserved Lanes			
At-Grade Transitways	8.0		3.0
Grade-Separated Transitways			
Queue Jumpers		Yes	
Station			
Location	Off-street	On-street	Off-street
Passing Capability	Bus pullouts		
ITS			
Transit Vehicle Prioritization		TSP	
Intelligent Vehicle Systems			
Service Plan			
Route Type	Limited	All Stop	All Stop
Average Station Spacing (mi)	0.71	0.56	0.30
Method of Schedule Control	Schedule	Schedule	Headway
Performance	2004 data	2004 data	2004 data
Maximum (Peak Hour) End-to-End Travel Time (min)	25	63	
Uncongested End-to-End Travel Time (min)	25	52	20
Average Speed in Peak Hour (mph)	19.2	13.4	
Average Uncongested Speed (mph)	19.2	16.2	9.0
% Travel Time Reduction in Corridor Before vs. After BRT	35%		
% Travel Time Reduction in Corridor Compared to Local Bus		21%	Overall avg of 25% faster than local bus routes
Survey of Customer Travel Times	(17% from limited service route)	0%	Very favorable

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Phoenix RAPID I-10 East	Phoenix RAPID I-10 West	Phoenix RAPID SR-51	Phoenix RAPID I-17
Running Way (mi)				
On-Street Mixed Lanes	6.5	4.8	12.3	8.0
On-Street Exclusive Bus Lanes				
Off-Street Mixed Lanes				
Off-Street Reserved Lanes	14.0	8.0	10.3	11.5
At-Grade Transitways				
Grade-Separated Transitways				
Queue Jumpers				
Station				
Location	On-street	On-street	On-street	On-street
Passing Capability	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts
ITS				
Transit Vehicle Prioritization	TSP	TSP		TSP
Intelligent Vehicle Systems	(1 signal)	TSP		(1 signal)
Service Plan	(1 signal)	TSP		Collision warning
Route Type	(1 signal)	All Stop	All Stop	
Average Station Spacing (mi)	Collision warning	Collision warning	Collision warning	Express
Method of Schedule Control				1.63
Performance	Express	Express	Express	Schedule
Maximum (Peak Hour) End-to-End Travel Time (min)	1.86	1.59	2.05	2004 data
Uncongested End-to-End Travel Time (min)	Schedule	Schedule	Schedule	52
Average Speed in Peak Hour (mph)	2004 data	2004 data	2004 data	
Average Uncongested Speed (mph)	37	34	48	22.5
% Travel Time Reduction in Corridor Before vs. After BRT				
% Travel Time Reduction in Corridor Compared to Local Bus	33.2	22.5	28.1	
Survey of Customer Travel Times				

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Pittsburgh East Busway	Pittsburgh South Busway	Pittsburgh West Busway
Running Way (mi)			
On-Street Mixed Lanes	0.4		0.4
On-Street Exclusive Bus Lanes			
Off-Street Mixed Lanes			
Off-Street Reserved Lanes			
At-Grade Transitways			
Grade-Separated Transitways	8.7	4.3	4.6
Queue Jumpers			
Station			
Location	Off-street	Off-street	Off-Street
Passing Capability	Passing lanes	Passing lanes	Passing lanes
ITS			
Transit Vehicle Prioritization			TSP
Intelligent Vehicle Systems	Collision warning	Collision warning	Collision warning
Service Plan			
Route Type	All-stop	All-stop	All-stop
Average Station Spacing (mi)	1.14	0.54	0.83
Method of Schedule Control	Schedule	Schedule	Schedule
Performance	2004 data	2004 data	2004 data
Maximum (Peak Hour) End-to-End Travel Time (min)	20	9	17
Uncongested End-to-End Travel Time (min)	18	9	14
Average Speed in Peak Hour (mph)	27.3	28.7	17.6
Average Uncongested Speed (mph)	30.3	28.7	21.4
% Travel Time Reduction in Corridor Before vs. After BRT	52%	55%	26%
% Travel Time Reduction in Corridor Compared to Local Bus			
Survey of Customer Travel Times			85% of passengers report shorter travel times with an average reduction of 14 min

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Sacramento	San Jose	Halifax
	E-Bus	Rapid 522	MetroLink
Running Way (mi)			
On-Street Mixed Lanes	8.0	25.0	12.1
On-Street Exclusive Bus Lanes			0.5
Off-Street Mixed Lanes			10.6
Off-Street Reserved Lanes	4.0		
At-Grade Transitways			
Grade-Separated Transitways			
Queue Jumpers			
Station			
Location	On- and off-street	On- and off-street	On- and off-street
Passing Capability			
ITS			
Transit Vehicle Prioritization	TSP	TSP	TSP
Intelligent Vehicle Systems			
Service Plan			
Route Type		Limited	Express
Average Station Spacing (mi)	0.47	0.86	3.3
Method of Schedule Control		Headway	
Performance			
Maximum (Peak Hour) End-to-End Travel Time (min)	43 min	88 EB, 100 WB	44 min
Uncongested End-to-End Travel Time (min)	34 min		
Average Speed in Peak Hour (mph)	11.2 mph	17.4 mph EB, 15.3 mph WB	
Average Uncongested Speed (mph)	14.1 mph		
% Travel Time Reduction in Corridor Before vs. After BRT	10%		33%
% Travel Time Reduction in Corridor Compared to Local Bus	5%	20%	33%
Survey of Customer Travel Times	No	Yes	Yes, rated excellent

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Ottawa Transitway			York	
	95	96	97	VIVA Blue	VIVA Purple
Running Way (mi)					
On-Street Mixed Lanes	2.1	2.1	2.1	20.3	17.1
On-Street Exclusive Bus Lanes				Some bus-only intersection lanes	Some bus-only intersection lanes
Off-Street Mixed Lanes	3.2	13.1	5.2		
Off-Street Reserved Lanes	8.7	3.8	1.2		
At-Grade Transitways	12.0	8.2	9.8		
Grade-Separated Transitways					
Queue Jumpers					
Station					
Location	On- and off-street	On- and off-street	On- and off-street	On- and off-street	On- and off-street
Passing Capability	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts
ITS					
Transit Vehicle Prioritization	TSP	TSP	TSP	TSP	TSP
Intelligent Vehicle Systems					
Service Plan					
Route Type			All-Stop	Limited Stop	Limited Stop
Average Station Spacing (mi)	0.95	1.20	0.60	1.10	1.00
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule
Performance					
Maximum (Peak Hour) End-to-End Travel Time (min)	65	75	59	74	67
Uncongested End-to-End Travel Time (min)	65	72	54	52	48
Average Speed in Peak Hour (mph)	22.0	19.0	16.0	17.0	16.0
Average Uncongested Speed (mph)	25.0	23.0	20.0	22.0	21.0
% Travel Time Reduction in Corridor Before vs. After BRT					
% Travel Time Reduction in Corridor Compared to Local Bus					
Survey of Customer Travel Times				Rated improved	Rated improved

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Bogotá	Guayaquil	Pereira
	Transmilenio	Metrovia	Megabus
Running Way (mi)			
On-Street Mixed Lanes			
On-Street Exclusive Bus Lanes			
Off-Street Mixed Lanes			
Off-Street Reserved Lanes			
At-Grade Transitways	52.0	10.0	17.0
Grade-Separated Transitways			
Queue Jumpers			
Station			
Location	Off-street	Off-street	Off-street
Passing Capability	Bus pullouts		
ITS			
Transit Vehicle Prioritization			
Intelligent Vehicle Systems			
Service Plan			
Route Type	Trunk-feeder (all-stop, express along trunk)	Trunk-feeder (all-stop along trunk)	Trunk-feeder (all-stop, limited, and express along trunk)
Average Station Spacing (mi)	0.40	0.28	0.46
Method of Schedule Control			
Performance			
Maximum (Peak Hour) End-to-End Travel Time (min)			
Uncongested End-to-End Travel Time (min)			
Average Speed in Peak Hour (mph)	14 - 16	14.0	13.0
Average Uncongested Speed (mph)	14 - 16	14.0	13.0
% Travel Time Reduction in Corridor Before vs. After BRT			
% Travel Time Reduction in Corridor Compared to Local Bus			
Survey of Customer Travel Times			

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Amsterdam	Caen	Edinburgh	Eindhoven
	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor
Running Way (mi)				
On-Street Mixed Lanes	1.9		1.9	2.2
On-Street Exclusive Bus Lanes	6.2	9.2	2.2	
Off-Street Mixed Lanes	2.5			
Off-Street Reserved Lanes				
At-Grade Transitways	14.9	0.1	0.9	7.2
Grade-Separated Transitways				
Queue Jumpers				
Station				
Location		On- and off-street	On- and off-street	On- and off-street
Passing Capability				
ITS				
Transit Vehicle Prioritization				TSP
Intelligent Vehicle Systems	Precision docking	Precision docking	Precision docking	Not being used
Service Plan				
Route Type	Limited express	All-stop	All-stop	All-stop
Average Station Spacing (mi)	0.9-1.2	0.2-0.25	0.2-0.25	0.34
Method of Schedule Control				
Performance				
Maximum (Peak Hour) End-to-End Travel Time (min)		30	3.2 (guideway segment)	
Uncongested End-to-End Travel Time (min)				
Average Speed in Peak Hour (mph)				
Average Uncongested Speed (mph)	23.5	12.5		13.0
% Travel Time Reduction in Corridor Before vs. After BRT			70% average in PM for guideway segment	
% Travel Time Reduction in Corridor Compared to Local Bus				
Survey of Customer Travel Times				

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Leeds	London	Rouen	Utrecht
	Superbus	Crawley	TEOR	Busway
Running Way (mi)				
On-Street Mixed Lanes		11.2	8.7	3.5
On-Street Exclusive Bus Lanes	3.8	3.7		2.0
Off-Street Mixed Lanes				
Off-Street Reserved Lanes				
At-Grade Transitways	2.2	0.9	14.9	4.8
Grade-Separated Transitways				
Queue Jumpers				
Station				
Location	On- and off-street	On- and off-street	On- and off-street	On- and off-street
Passing Capability				
ITS				
Transit Vehicle Prioritization	TSP		TSP	TSP
Intelligent Vehicle Systems	Precision docking	Precision docking	Precision docking	
Service Plan				
Route Type	Trunk-feeder	All-stop	All-stop	All-stop
Average Station Spacing (mi)		0.25	0.33	
Method of Schedule Control				
Performance				
Maximum (Peak Hour) End-to-End Travel Time (min)		Up to 30% reduction in journey times		
Uncongested End-to-End Travel Time (min)				
Average Speed in Peak Hour (mph)				
Average Uncongested Speed (mph)		12.5	10.3	
% Travel Time Reduction in Corridor Before vs. After BRT	3 min outbound, up to 11 min inbound		70% average in PM for guideway segment	
% Travel Time Reduction in Corridor Compared to Local Bus				
Survey of Customer Travel Times				

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Adelaide	Brisbane		Sydney
	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way
Running Way (mi)				
On-Street Mixed Lanes				
On-Street Exclusive Bus Lanes				
Off-Street Mixed Lanes				
Off-Street Reserved Lanes				
At-Grade Transitways				
Grade-Separated Transitways	7.46	10.3	1.7	13.0
Queue Jumpers				
Station				
Location	Off-street	Off-street	Off-street	On- and off-street
Passing Capability	Passing at interchanges	Bus pullouts	Bus pullouts	Bus pullouts
ITS				
Transit Vehicle Prioritization	Passive priority			TSP
Intelligent Vehicle Systems	Precision docking			
Service Plan				
Route Type	All-stop express/semi express	All-stop & express, including express to CBD with no stops	All-stop	All-stop
Average Station Spacing (mi)	3.10	1.00	0.41	0.54
Method of Schedule Control				
Performance				
Maximum (Peak Hour) End-to-End Travel Time (min)	29 (TTP to city)	21	21	64
Uncongested End-to-End Travel Time (min)	23 (TTP to city)	20	20	60
Average Speed in Peak Hour (mph)	15.5 / 25 (TTP to city)	29.3/47.1	5.5	18
Average Uncongested Speed (mph)	17.3 / 28 (TTP to city)	30.8/49.5	5.8	19
% Travel Time Reduction in Corridor Before vs. After BRT	40% (approx)	65% in peak	0	
% Travel Time Reduction in Corridor Compared to Local Bus	66%			
Survey of Customer Travel Times	No	Yes	Yes	No

Exhibit 3-5: BRT Elements by System and Travel Time (cont'd)

	Sydney		Beijing	Kunming
	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Busway Network
Running Way (mi)				
On-Street Mixed Lanes				
On-Street Exclusive Bus Lanes				
Off-Street Mixed Lanes				
Off-Street Reserved Lanes				24.9
At-Grade Transitways	4.4	8.7		
Grade-Separated Transitways			8.1	
Queue Jumpers				
Station				
Location	Off-street	On- and off-street	Off-street	
Passing Capability	Bus pullouts	Bus pullouts	Multiple lanes	
ITS				
Transit Vehicle Prioritization			TSP	
Intelligent Vehicle Systems				
Service Plan				
Route Type	All-stop	All-stop	All-stop	All-stop
Average Station Spacing (mi)	0.42	0.50	.57	
Method of Schedule Control				
Performance				
Maximum (Peak Hour) End-to-End Travel Time (min)	20	38	37	
Uncongested End-to-End Travel Time (min)	17	38		
Average Speed in Peak Hour (mph)	14.0	16.8	14.9	9.4
Average Uncongested Speed (mph)	16.4	16.8		
% Travel Time Reduction in Corridor Before vs. After BRT			38%	Speeds up 68%
% Travel Time Reduction in Corridor Compared to Local Bus				
Survey of Customer Travel Times				

Station Dwell Time

Description of Station Dwell Time

Station dwell time represents the second major component of end-to-end travel time (in addition to running time). Station dwell time is the amount of time spent by passengers while a vehicle is stopped at a station. The dwell time represents the time required for the vehicle to load and unload passengers at the transit station. The report on "Operational Analysis of Bus Lanes on Arterials" states that station dwell time can comprise as much as 30 percent (a significant share) of total travel times for transit. It also states that dwell time can also make up to as much as 40 percent of total delay time depending on the level of congestion. Dwell time depends on:

- number of passengers boarding or alighting per door channel - higher passenger loads at stations increase dwell time while multiple places to board and alight disperses these loads, thereby reducing dwell time
- fare collection system—processing fares upon boarding directly increases loading times; pre-processing fares and/or reducing transaction times on vehicles can reduce loading times
- vehicle occupancy—congestion inside the vehicle requires extra time to load and unload passengers

Effects of BRT Elements on Station Dwell Time

The BRT elements that impact station dwell time most strongly are discussed below.

Stations - Curb Design

Level platforms minimize the "gap" between the BRT vehicle floor and the station platform edge, greatly speeding the boarding and alighting process. No-gap, level vehicle, floor-to-platform boarding and alighting has the added benefit of permitting wheelchair users to board and alight BRT vehicles without a lift, ramp, or assistance from a vehicle operator, thereby eliminating the time spent deploying ramps or lifts.

Raised curbs achieve some of the benefits of level platforms without the need for precision docking but require extra time for ramp deployment for the mobility impaired.

Stations—Platform Layout

Platform layouts that do not constrain the number of vehicles, specifically **extended platforms** (with or without **assigned berths**) that can load and unload passengers, decrease the amount of time vehicles spend at stations waiting in vehicle queues.

Vehicles—Vehicle Configuration

Vehicle configurations with low floors (whether **conventional standard**, **stylized standard**, **conventional articulated**, or **stylized articulated**) facilitate boarding and alighting, especially of mobility impaired groups—persons with disabilities, the elderly, children, and persons with packages. For low-floor vehicles, passenger service times could be reduced 20 percent for boarding times, 15 percent for front alighting times, and 15 percent for rear alighting times.

Specialized BRT vehicles with 100 percent low-floor vehicles have the great advantage of shorter boarding and alighting times and the ability to place an additional door behind the rear axle.

Vehicles—Passenger Circulation Enhancement

All types of passenger circulation facilitate lower dwell times.

Additional door channels (with wider and more numerous doors) can dramatically reduce the time for passengers to board and alight. BRT systems that incorporate some form of secure, non-driver involved fare collection (on-board conductor-validated system, off-board barrier system, or off-board barrier-free system) can take advantage of multiple-door boarding.

Vehicles that include an **alternative seat layout** with wider aisles in the interior also reduce dwell times, especially when there are significant standing loads, by reducing passenger congestion within the vehicle and reducing time for boarding and alighting.

Although a small percentage of passengers board in wheelchairs, the dwell times for these customers can be significant. The typical wheelchair-lift cycle times range from 60 to 200 seconds per boarding for high-floor buses (including time to secure the wheelchair). With a low-floor bus, the typical wheelchair ramp cycle time ranges from 30 to 60 seconds per boarding, which includes time to secure the wheelchair. **Enhanced wheelchair securement** devices are being developed and can reduce dwell times further; the extent of the impact is still being measured.

Fare Collection—Fare Collection Process

Fare collection processes that allow multiple door boarding and do not require the involvement of the driver (**on-board conductor-validated, off-board barrier-enforced, or off-board barrier-free/proof-of-payment**) can provide significant reductions in boarding times.

Fare Collection—Fare Media and Payment Options

For options where fare transactions take place on the vehicle, the fare transaction media has additional impacts on station dwell time. Compared to fare collection by a driver using exact change, **flash pass systems** or **electronic systems using tickets or passes** can reduce passenger boarding time by 13 percent from an average of 3.5 to 4 seconds per passenger. **Smart card** technologies are most effective in this respect; **magnetic stripe card** technologies are less effective.

ITS—Intelligent Vehicle Systems

Precision docking has the potential to reduce station dwell times for two reasons: it allows all passengers, especially the mobility impaired, to board and alight without climbing up and/or down stairs, and some BRT systems (e.g., Bogotá Transmilenio) use systems that ensure that vehicles stop in the same location, thus ensuring orderly queuing for boarding.

Service and Operations Plan—Service Frequency
Increasing service frequency reduces the number of passengers that can accumulate at the station, reducing the time associated with loading them.
Service and Operations Plan—Method of Schedule Control
Headway-based schedule control makes headways more regular, ensuring even loads and loading times.

Performance of Existing Systems

Several BRT systems have demonstrated low dwell times compared to conventional bus transit. This section characterizes this experience in three sections: a summary of relevant research, profiles of noteworthy experience, and a summary of BRT systems and the characteristics that affect dwell time, as well as any available performance data.

Research Summary

Several studies performed for conventional transit service suggest how implementation of certain BRT elements can achieve dwell time savings.

Exhibit 3-6 highlights typical passenger service times for a standard floor bus. Exhibit 3-7 shows loading times as a function of available door channels. Increasing the number of door channels available for loading reduces loading time. This is critical where the number of passengers at stations is high.

Exhibit 3-6: Passenger Service Times by Floor Type

Transit Agency		Boarding Times (sec)		Alighting Times (sec)	
		Low-Floor	High-Floor	Low-Floor	High-Floor
Ann Arbor Transportation Authority					
Revenue:	Cash	3.09	3.57	1.32	2.55
	No Cash	1.92	2.76	2.17	2.67
Shuttle:	No Fare	1.91	2.26	Not reported	Not reported
Victoria Regional Transit System		3.02	3.78	1.87	3.61
				2.13	1.84
Vancouver Regional Transit System		N/A	3.78	N/A	2.62
					1.43
St. Albert Transit					
Single Boarding		3.61	4.27		
Two Boarding		6.15	7.27	Not reported	Not reported
Senior Boarding		3.88	6.10		
Kitchner Transit		2.23	2.42	1.16	1.49

Source: Bus Rapid Transit: Case Studies in Bus Rapid Transit, Chapter 6.

Exhibit 3-7: Multiple Channel Passenger Service Times per Total Passenger with a High-Floor Bus (sec/passenger)

Available Door Channels	Boarding	Front Alighting	Rear Alighting
1	2.5	3.3	2.1
2	1.5	1.8	1.2
3	1.1	1.5	0.9
4	0.9	1.1	0.7
6	0.6	0.7	0.5

Source: Transit Capacity and Quality of Service Manual, 2nd Edition

The *Transit Capacity and Quality of Service Manual, 2nd Edition* estimates the average boarding times per passenger for a conventional single-door boarding bus fare collection system where the operator(s) enforces fare payment. These are shown in Exhibit 3-8.

Exhibit 3-8: Bus Passenger Service Times (sec/passenger)

Fare Payment Method	Observed Range	Default (Single-Door Boarding)
BOARDING		
Pre-payment (e.g., passes, no fare, free transfer, pay on exit)	2.25–2.75	2.5
Smart card	3.0–3.7	3.5
Single ticket or token	3.4–3.6	3.5
Exact change	3.6–4.3	4.0
Swipe or dip card	4.2	4.2
ALIGHTING		
Rear door	1.4–2.7	2.1
Front door	2.6–3.7	3.3

Note: Add 0.5 sec to boarding times if standees are present on the bus. Subtract 0.5 sec/ passenger from boarding times and 1.0 seconds/passenger from front-door alighting times on low-floor buses.

Sources: Transit Capacity and Quality of Service Manual, 2nd Edition, p. 4-5; "BRT Implementation Guidelines," Table 8-7.

The *Transit Quality of Service Manual* indicates that proof-of-payment systems can provide up to a 38 percent reduction in boarding times, with commensurate reductions in dwell times as well. Multiple-door channels for boarding and alighting can reduce passenger service times even further, to a fraction of other fare collection approaches. For example, two-, three-, four-, and six-door channels can reduce the 2.5 seconds per total passenger required to board under complete pre-paid fare system to 1.5, 1.1, 0.9, and 0.6 seconds per total passenger boarding at a particular stop, respectively (*Transit Capacity and Quality of Service Manual, 2nd Edition*, Exhibit 4-2).

System Performance Profiles

Transmilenio, Bogotá

The Transmilenio in Bogotá uses multiple BRT elements to achieve an extremely short station dwell time of 0.33 seconds per passenger. Station platforms are the same height as the floor of the buses, stations feature one to five platforms and one or two access points, buses have four large left-side doors that are coordinated with the station doors, and fare collection occurs at the station entrance using pre-paid contactless smart card technology.

The prepaid farecards can be purchased only inside the stations, which can cause queuing problems and create congestion in the station area. Placing fare machines outside the stations would reduce wait times to purchase or reload cards ("Report on South American Bus Rapid Transit Field Visits: Tracking the Evolution of the TransMilenio Model: Final Report: December 2007" and "Applicability of Bogotá's TransMilenio BRT System to the United States, Final Report").

MAX, Las Vegas and TEOR, Rouen

Both the MAX system in Las Vegas and the TEOR system in Rouen, France utilize an optical guidance precision docking system. This system, in combination with vehicle floor-height station platforms, provides level, no-gap boarding and alighting, thus greatly reducing station dwell times. The MAX reports average dwell times of just 15 to 20 seconds, while the TEOR reports an average dwell time of 6.3 seconds. (Note that the Las Vegas MAX optical guidance system is no longer operational.)

Transitway, Ottawa

In a demonstration project between 1982 and 1984, Ottawa's transit agency, OC Transpo, replaced standard 40-ft buses with 60-ft articulated buses on one route and introduced a proof-of-payment (POP) fare collection scheme. Under this POP fare collection scheme, passengers with valid passes or transfers (about 68 percent of riders on the route) could board at any of the three doors of the articulated bus. Prior to POP implementation, the bus operator enforced fare payment on this route, and all passenger boardings took place only at the front door.

The demonstration project showed that POP implementation yielded better performance through improvements in schedule adherence and on-time performance. Average dwell times for the articulated buses were reduced by an estimated 13 to 21 percent, based on dwell time survey data. Average bus running times were reduced by about 2 percent. There was no evidence that POP implementation increased the fare evasion rate. Due to the increased capacity of the articulated buses, OC Transpo was able to substitute two articulated buses for three standard buses on the route, realizing benefits from fewer driver hours and reduced operating costs.

BRT Elements by System and Station Dwell Time

Exhibit 3-9 presents a summary of BRT elements that affect station dwell time from 35 cities with BRT systems. It also presents performance results, calculated as mean station dwell times.

A focus on reducing dwell times is not yet standard among BRT systems in North America. This partly reflects the dominance of on-street curbside lane operations, which may limit the ability to implement features that reduce dwell time such as level boarding, off-board fare collection, and extended berthing platforms. As a result, many BRT systems in the U.S., especially those that operate on arterial streets, still load and unload passengers in the same fashion as conventional bus service, yielding minimal dwell time reductions. The increasing introduction of smart card and magnetic swipe fare media for on-board fare collection throughout U.S. transit systems should help to reduce dwell times for these arterial BRT systems; agencies in Boston, Chicago, Honolulu, Miami, and Oakland have incorporated smart cards or magnetic swipe cards as part of systemwide implementations. Moreover, some agencies are implementing off-board fare collection for arterial BRT; for example, the VIVA, which operates in Ontario's York Region, uses proof-of-payment off-board fare collection even though it currently runs in on-street curbside lanes.

In addition, the greater use of low-floor buses will help to reduce boarding time by reducing the height differential between the curb and bus. Almost all U.S. BRT systems are currently served by low-floor buses.

Variations in the fare payment process can yield dwell time reductions. For example, Pittsburgh's busways follow a policy of collecting fares on trips away from downtown at the destination station. Passengers thus board through all doors in downtown, speeding up the service as it travels through downtown. Orlando's LYMMO operates with no fares, allowing passengers to enter and exit through all doors. The Las Vegas MAX, the Los Angeles Metro Orange Line, the Eugene EmX, and the Cleveland HealthLine are the only BRT systems in the U.S. that use off-board fare payment, multiple-door boarding, and level or raised platforms as part of a comprehensive design to reduce dwell times. The Las Vegas MAX and Cleveland HealthLine also incorporate guidance equipment to help achieve level boarding (although the Las Vegas optical guidance system is not in use).

By contrast, use of alternative fare collection processes, especially off-board systems, is more common outside the U.S. Many conventional bus operations that have relatively less expensive labor costs, such as in Latin America, use on-board conductor-validated systems, thereby eliminating the involvement of the driver. Off-board fare collection processes are common among systems with high volumes of passenger loads at stations. Off-board barrier-enforced systems are common in Latin America (Curitiba, Bogotá and Pereira, Quito and Guayaquil) and are being introduced in Beijing. The Transmilenio in Bogotá boasts an impressively-low 0.33 seconds per passenger for dwell time. Off-board barrier-free systems are common in Canada (OC Transpo's Transitway in Ottawa and York Region's VIVA) and Europe (several systems in the Netherlands and France). Several systems demonstrate consistently low average station dwell times as a result, including the Zuidtangent in Amsterdam (10-15 seconds total dwell time), the Western Corridor in Eindhoven (10 seconds total dwell time), and TEOR routes in Rouen (6.3 seconds total dwell time).

Only 10 cities provided data on their BRT systems' mean station dwell time, and the data reflect with various factors, including total station dwell time, dwell time per passenger, and as a percentage of total trip time. As a result, it is not possible to draw broad conclusions about the effect of individual BRT elements on dwell times. Systems that provided data incorporate either level to near-level boarding or standard platforms with multiple vehicle platform lengths. Rouen, Las Vegas, Pittsburgh, Bogotá, Eindhoven, and Amsterdam each have level or raised-platform boarding, while Adelaide, Brisbane, Miami, and Ottawa use standard boarding but feature platforms that can accommodate three, four, or five buses at a time.

Most of these 10 cities use off-board fare collection or proof-of-payment-enforced on-board collection. The exceptions are the two U.S. systems in Miami and Pittsburgh, and Brisbane, which also reports the longest dwell time of these systems—180 seconds. Most, but not all, employ high service frequency—headways of five minutes or less—but there was no obvious correlation between frequency level and reduced dwell time. Finally, of the six systems with the lowest reported dwell times, Rouen, Las Vegas, Eindhoven, Amsterdam, and Adelaide all use some form of precision docking; the exception is Bogotá.

Exhibit 3-9: BRT Elements by System and Station Dwell Time

	Albuquerque	Boston Silver Line		Chicago			Cleavland
	Rapid Ride	Washington Street	Waterfront	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Stations							
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Level platform
Platform Layout (# vehicles accommodated)	1	1	1 above ground, 3 underground	1	1	1	1
Vehicles							
Configuration	Articulated	Stylized articulated	Articulated	Conventional standard	Stylized articulated	Articulated	Articulated
Floor Height	Low	Step low	Low	High	Low	Low	Low
Fare Collection							
Fare Collection Process	Pay on-board	Pay on-board	Barrier at 3 underground stations; others are Pay On-Board	Pay on-board	Pay on-board	Pay on-board	Off-board
Fare Media and Payment Options	Cash, paper	Cash, paper transfers, magnetic stripe, smart card	Cash, paper ticket, smart card	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe	
ITS							
Intelligent Vehicle Systems							
Service Plan							
Peak Service Frequency (min)	11	4	10	9	11	12	15
Method of Schedule Control		Schedule	Schedule	Schedule	Schedule	Schedule	Schedule
Performance							
Mean Dwell Time (sec)							

Exhibit 3-9: BRT Elements by System and Station Dwell Time (cont'd.)

	Eugene	Honolulu			Kansas City	Las Vegas	Los Angeles	Los Angeles
	EmX	City Express A	City Express B	County Express C	MAX	North Las Vegas MAX	Orange Line	Metro Rapid (All Routes)
Stations								
Curb Design	Raised curb	Standard curb	Standard curb	Standard curb		Raised curb	8" curb	Standard curb
Platform Layout (# vehicles accommodated)	1	1	1	1	1	1	3	1
Vehicles								
Configuration	Articulated	Articulated	Standard	Articulated	Stylized conventional	Stylized articulated	Stylized articulated	Stylized standard and articulated
Floor Height	Low	Low	High	Low	Low	Low	Low	Low floor
Fare Collection								
Fare Collection Process	None	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Proof-of-payment	Proof-of-payment	Pay on-board
Fare Media and Payment Options	None	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe		Magnetic stripe	Tickets from TVM and standard paper passes	Cash and paper passes
ITS								
Intelligent Vehicle Systems						Precision Docking		-
Service Plan								
Peak Service Frequency (min)	10	15	15	30	9	12	4	2-10
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule	Headway		Headway
Performance								
Mean Dwell Time (sec)						15 to 20		

Exhibit 3-9: BRT Elements by System and Station Dwell Time (cont'd.)

	Miami	Oakland	Orlando	Phoenix	Phoenix	Phoenix	Phoenix
	Busway	Rapid San Pablo Corridor	LYMMO	RAPID I-10 East	RAPID I-10 West	RAPID SR-51	RAPID I-17
Stations							
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)	3	1	2	1	1	1	1
Vehicles							
Configuration	Conventional standard and minis	Stylized standard	Conventional standard	Stylized standard	Stylized standard	Stylized standard	Stylized standard
Floor Height	Step low	Step low	Low	Step low	Step low	Step low	Step low
Fare Collection							
Fare Collection Process	Pay on-board	Pay on-board	Free	Pay on-board	Pay on-board	Pay on-board	Pay on-board
Fare Media and Payment Options	Cash, paper, magnetic stripe	Cash, paper, smart card		Cash, paper	Cash, paper	Cash, paper	Cash, paper
ITS							
Intelligent Vehicle Systems				Collision warning	Collision warning	Collision warning	Collision warning
Service Plan							
Peak Service Frequency (min)	6	12	5	10	10	10	10
Method of Schedule Control	Schedule	Schedule	Headway	Schedule	Schedule	Schedule	Schedule
Performance	2004 data			2004 data	2004 data	2004 data	2004 data
Mean Dwell Time (sec)	45-60			45-60	45-60	45-60	45-60

Exhibit 3-9: BRT Elements by System and Station Dwell Time (cont'd.)

	Pittsburgh East Busway	Pittsburgh South Busway	Pittsburgh West Busway	Sacramento E-Bus	San Jose Rapid 522	Halifax MetroLink
Stations						
Curb Design	Raised curb	Raised curb	Raised curb		Standard curb	Standard curb
Platform Layout (# vehicles accommodated)					2	2
Vehicles						
Configuration	Conventional standard and articulated	Conventional standard and articulated	Conventional standard and articulated	Standard	Stylized standard and articulated	Stylized standard
Floor Height	High	High	High	Low	Low	Low
Fare Collection						
Fare Collection Process	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay on-board
Fare Media and Payment Options	Cash, paper	Cash, paper	Cash, paper	Cash, passes	Cash, paper passes, (smart cards in development)	Cash, ticket, passes
ITS						
Intelligent Vehicle Systems	Collision warning	Collision warning	Collision warning			
Service Plan						
Peak Service Frequency (min)	0.58		1.33	15 min	15	10
Method of Schedule Control	Schedule	Schedule	Schedule		Headway	
Performance	2004 data					
Mean Dwell Time (sec)	35 at inner stations, 47-60 at outer stations					

Exhibit 3-9: BRT Elements by System and Station Dwell Time (cont'd.)

	Ottawa Transitway			York		Bogotá	Guayaquil	Pereira
	95	96	97	VIVA Blue	VIVA Purple	Transmilenio	Metrovia	Megabus
Stations								
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Level platform	Level Platform	Level Platform
Platform Layout (# vehicles accommodated)	3	3	3	1	1	2 - 5		1- 2
Vehicles								
Configuration	Articulated	Standard	Articulated	Articulated	Standard	Stylized articulated	Stylized standard and articulated	Stylized articulated
Floor Height	14.5 - 16" 11.5" kneeling	14.5 - 16" 11.5" kneeling	14.5 - 16" 11.5" kneeling	Low	Low	0.9 m		0.9 m
Fare Collection								
Fare Collection Process	Proof-of-payment	Proof-of-payment	Proof-of-payment	Proof-of-payment	Proof-of-payment	Barrier (verify at station entrances / exits)	Barrier	Barrier (verify at station entrances)
Fare Media and Payment Options	Cash, paper tickets, passes	Cash, paper tickets, passes	Cash, paper tickets, passes	Paper tickets, passes	Paper tickets, passes	Smart cards	Cash, smart cards	Smart cards
ITS								
Intelligent Vehicle Systems								
Service Plan								
Peak Service Frequency (min)	3-4	3-6	12	5	10	1-3	4-6	–3-5
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule			
Performance								
Mean Dwell Time (sec)	4-11% of total trip time for system	4-11% of total trip time for system	4-11% of total trip time for system			0.33 per passenger		

Exhibit 3-9: BRT Elements by System and Station Dwell Time (cont'd.)

	Amsterdam	Caen	Edinburgh	Eindhoven	Leeds	London	Rouen	Utrecht
	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus	Crawley	TEOR	Busway
Stations								
Curb Design	Level platform	Level platform	Level platform	Level platform	Level platform, raised curb	Standard curb	Level platform	Level platform
Platform Layout (# vehicles accommodated)								
Vehicles								
Configuration	Articulated	Bi-articulated	Standard single and double deck	Articulated,	Standard	Stylized articulated	Stylized standard and articulated	Stylized articulated
Floor Height	Low	Low	Low	Low	Low	Low	Low	Low
Fare Collection								
Fare Collection Process	Pay on-board or proof-of-payment	Pay on-board or proof-of-payment	Pay on-board or proof-of-payment	Proof-of-payment, pay on-board machine, no driver payment	Pay on-board	Pay on-board	Off-board	Pay on-board or proof-of-payment
Fare Media and Payment Options	Paper (Strippenkart)	Smart cards, magnetic tickets	Cash coin (exact change) or smart card	Paper (Strippenkart)	Cash and paper only	Cash	Magnetic stripe	Paper (Strippenkart)
ITS								
Intelligent Vehicle Systems	Precision docking	Precision docking	Precision docking	Not being used	Precision docking	Precision docking	Precision docking	
Service Plan								
Peak Service Frequency (min)	7.5 - 8	3-6 (where routes overlap)	3	8	2-8	10	3	2-4
Method of Schedule Control								
Performance								
Mean Dwell Time (sec)	10-15l			10			6.3	

Exhibit 3-9: BRT Elements by System and Station Dwell Time (cont'd.)

	Adelaide	Brisbane		Sydney			Beijing	Kunming
	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Busway network
Stations								
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Level platform	Standard curb
Platform Layout (# vehicles accommodated)	3- and 4-bus length	Standard 4 max 5	Standard 4 max 5	Standard 2 max 6	Standard 2 4 at termini			60 m platform length
Vehicles								
Configuration	Standard articulated, standard rigid	Standard rigid	Standard rigid	Standard rigid	Standard rigid	Standard rigid	Articulated	Standard
Floor Height	Step high, step low	Mainly step low, some step high	Mainly step low, some step high	Step low	Step high	Step high, step low	Low	High
Fare Collection								
Fare Collection Process	Pay on-board (80% pre-pay multi-rider ticket)	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay attendants at station	Pay on-board
Fare Media and Payment Options	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, smart cards	Cash, IC cards
ITS								
Intelligent Vehicle Systems	Precision docking							
Service Plan								
Peak Service Frequency (min)	1.1	16-sec headway at Buranda Station	4.6	10.0	8.6	4.0		
Method of Schedule Control								
Performance								
Mean Dwell Time (sec)	30	180	180					

Wait Time and Transfer Time

Description of Wait Time and Transfer Time

Wait time is the amount of time a passenger spends at a station before boarding a particular transit service. Because passengers perceive wait time as more of a burden than time spent in a moving vehicle (as much as three times a burden), reducing wait time is an important aspect of designing a BRT service. BRT systems often are planned such that the service (especially the trunk line, all-stops service) is frequent enough during peak periods so customers without a schedule can arrive randomly and still experience brief waits.

Transfer time represents the amount of time passengers spend transferring from one BRT service to another or to other transit services (e.g., local bus routes and rail). Reducing the time required to travel within the station from one vehicle to the next and the time spent waiting for the second service reduce this element of travel time.

Effects of BRT Elements on Wait Time and Transfer Time

Service frequency and reliability are the primary determinants of wait time, although other elements such as passenger information systems affect the perception of wait time. In addition to those factors that affect wait time, primary factors affecting transfer time are station physical design and transit route network design.

Stations—Station Location
The design of stations can facilitate lower transfer times, walking distances, and fewer level changes. Off-street, on-line stations with highway rights-of-way increase transfer time to connecting transit service.
ITS—Operations Management
An **automated scheduling and dispatch system** along with **transit vehicle tracking** ensures even headways (for lower wait times) and connection protection for those passengers transferring among systems or vehicles. Transit vehicle tracking also enables the passenger information to be collected and disseminated.

ITS—Passenger Information
Real-time passenger information systems do not directly impact wait time. However, by providing current information on the status of the approaching vehicles, real-time passenger information systems allow passengers to adjust their wait time expectations or spend their wait time in other activities, reducing the burden that passengers associate with waiting. **Trip itinerary planning** and **traveler information on person** (through PDAs or mobile phones) give passengers advance information on closest stations, next vehicle arrival, and required transfers. **Traveler information on vehicles** and **traveler information at stations** can inform passengers on next vehicle arrival and can direct passengers to the correct location for transfers (berth or platform position.)
Service and Operations Plan—Service Frequency
Service frequency is the key determinant of wait time and transfer time. Since BRT systems can cost-effectively use (smaller) standard-size vehicles, the operation of a trunk line can support higher frequencies of service.
Service and Operations Plan—Route Structure
BRT route structures that incorporate multiple route types converging onto a common trunk can increase the number and types of services available to transit passengers at high-volume stations. Multiple routes traveling the same corridor increase the frequency along the corridor and reduce the amount of time waiting for BRT service. BRT route networks also can be constructed to eliminate transfer time altogether. Routes can combine local feeder and BRT trunk service, eliminating the need to disembark at the station and transfer for passengers who access the transit network at locations away from the primary BRT route.
Service and Operations Plan—Method of Schedule Control
For high frequency services, **headway-based scheduling** can regulate headways and reduce spikes in waiting time due to vehicle bunching.

Performance of Existing Systems

System Performance Profiles

Several systems suggest how BRT elements can reduce wait times and transfer times.

Orange Line, Los Angeles

In October 2005, the Los Angeles Metropolitan Transportation Authority (Metro) opened the Orange Line, one of the first systems in the U.S. to incorporate a comprehen sive set of BRT features. The Orange Line primarily operates on a dedicated busway with high-capacity articulated buses, substantial stations, near-level boarding, off-board fare payment, and headway-based schedules. Metro incorporated several features that reduce wait and transfer times, as well as customer perceptions of wait time. On weekdays, buses run at four- to six-minute headways during peak hours, and every 10 minutes off-peak. This frequency means that passengers do not need to consult a schedule before heading to a station to catch a bus, reducing both actual passenger wait time and the frustration that can result from waiting. To further reduce passenger perception of wait time, the stations feature real-time bus information signs. The stations also can accommodate multiple bus arrivals, which helps avoid the problem of bus bunching that can result from very short headways. Metro also timed the Orange Line schedule to coordinate with the schedule of the Red Line subway in an effort to ease transfers to the subway at the Orange Line's Hollywood Station eastern terminus. The connection to the subway occurs at street level, however, requiring passengers to walk a short distance and cross some vehicle traffic.

South Busway, Miami

The Miami Busway is a two-lane, at-grade, bus-only roadway adjacent to US 1. The 13-mile busway was implemented in two phases; the first 8.5 miles of the busway opened in 1997, and the final 4.5 mile segment opened in late 2007. The at-grade busway passes through many signalized intersections and terminates at a Metrorail station. Nine bus routes operate on all or part of the busway. There are three busway-only routes: Busway Local, which serves all stops; Busway Flyer, a limited-stop super-express service; and Busway MAX, a semi-express or skip-stop service. The other regular lines use the busway for a portion of their route. Since all nine routes converge onto the same busway trunk, they provide a very high combined frequency during AM and PM peak times of 29-30 vehicles per hour, making wait time low. The Dadeland South Intermodal Metrorail Station offers a seamless connection between rail and busway passengers, although passengers must exit the Metrorail fare area to access the busway bays for boarding and alighting.

London Bus (Non-BRT)

In London, England, an evaluation of the London Transport Countdown System (a real-time bus arrival information system) revealed that 83 percent of those surveyed believed that time passed more quickly by having the real-time information system at the stop. Also, 65 percent of those surveyed felt they waited a shorter time, with the average perceived wait time dropping from 12 minutes to 8.5 minutes, a 28 percent reduction.

BRT Elements by System and Wait Time and Transfer Time

Exhibit 3-10 presents those characteristics that affect the time associated with waiting for transit service and transferring between services for BRT systems in 35 cities worldwide. Performance measures include the following:

- average wait and transfer time
- percent of passengers requiring a transfer
- customer perception of wait time and transfer time

Few systems report such data, so it is difficult to make broad conclusions about the impact of specific BRT elements on wait and transfer times, but some trends can be noted. As expected, systems where the frequency was improved and spacing between vehicles was regulated yielded positive passenger ratings of wait time. In addition, integrated networks such as Pittsburgh's busways resulted in reduced wait time along trunk segments and reduced time associated with transferring. Many passengers do not have to transfer at all, while passengers who do still transfer report improvements in the ease of transferring.

Overall, the most frequent tools to reduce wait and transfer time, as well as passenger perceptions of wait time, are passenger information systems and frequency of service. Most of the U.S. systems either have bus arrival information at the stations and on the vehicles or are planning to implement these features. They also have much shorter headways than typical local bus service. Almost all of the U.S. systems feature peak headways of under 12 minutes, with three others offering 15-minute headways. In systems in other parts of the world, passenger information and high frequency are also the primary elements for reducing wait and transfer times. The headways are typically much shorter than the U.S. systems. About two-thirds feature headways under 6 minutes, while most of the remaining systems have 6- to 10-minute headways.

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time

	Albuquerque	Boston Silver Line		Chicago	Chicago	Chicago	Cleveland	Eugene
	Rapid Ride	Washington Street	Waterfront	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine	EmX
Stations								
Location	On-street	On-street	On- and off-street	On-street	On-street	On-street	On-street	On-street, transit center
ITS								
Automatic Vehicle Location (AVL)	GPS	GPS	GPS, dead reckoning in tunnel				GPS	GPS
Automatic Scheduling and Dispatch		None	CAD				Yes	CAD
Passenger Information	At station, on vehicle LED Nextbus signs	VMS at stations and in-vehicle	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements				At stations	Vehicle, web
Service Plan								
Route Structure	Overlapping route		New service & replacing local service				Replaced existing route	Replaced existing route
Peak Service Frequency (min)	11	4	10	9	11	12	15	10
Method of Schedule Control		Schedule	Schedule	Schedule	Schedule	Schedule	Schedule	Schedule
Performance								
Average Wait and Transfer Time (min)								
Percent of Passengers Requiring a Transfer	45%							
Customer Perception of Wait Time and Transfer Time		60.2% of surveyed passengers rated Frequency of Service above average or excellent	59% rated Frequency of Service as above average or excellent					

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time (cont'd.)

	Honolulu	Honolulu	Honolulu	Kansas City	Las Vegas	Los Angeles	Los Angeles
	City Express A	City Express B	County Express C	MAX	North Las Vegas MAX	Orange Line	Metro Rapid (All Routes)
Stations							
Location	On-street	On-street	On-street	On-street	On-street	Off-street	On-street
ITS							
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	GPS	Orbital	GPS, loop detectors	GPS, loop detectors
Automatic Scheduling and Dispatch					CAD/AVL		
Passenger Information	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations	Real-time at all stations, trip planning	Station, telephone, internet, on-vehicle electronic displays	Nextbus VMS	Nextbus VMS at stations, Telephone, Internet
Service Plan							
Route Structure	Overlaps local route	Overlaps local route	Overlaps local route				Replaced existing route
Peak Service Frequency (min)				12			
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Headway		Headway?
Performance							
Average Wait and Transfer Time (min)	8	7	7.5		7.8		
Percent of Passengers Requiring a Transfer	11%	38%	23%				
Customer Perception of Wait Time and Transfer Time							Passengers rate Metro Rapid Frequency at 3.76 out of 5, compared to 3.15 for the former Limited Bus

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time (cont'd.)

	Miami	Oakland	Orlando	Phoenix	Phoenix	Phoenix	Phoenix
	Busway	Rapid San Pablo Corridor	LYMMO	RAPID I-10 East	RAPID I-10 West	RAPID SR5-1	RAPID I-17
Stations							
Location	Off-street	On-Street	Off-street	On-street	On-street	On-street	On-street
ITS							
Automatic Vehicle Location (AVL)		GPS	AVL/Wi-Fi	Orbital	Orbital	Orbital	Orbital
Automatic Scheduling and Dispatch		Yes		Yes	Yes	Yes	Yes
Passenger Information	Traveler Information at stations and on vehicle	Real-time arrival at stations; traveler info on vehicle and via PDA	Traveler Information at stations and on vehicle; web-based	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.
Service Plan							
Route Structure	Integrated network of routes	Overlay onto local route	Replaced local downtown circulator	Express routes	Express routes	Express routes	Express routes
Peak Service Frequency (min)	10	12	5	10	10	10	10
Method of Schedule Control	Schedule	Schedule	Headway	Schedule	Schedule	Schedule	Schedule
Performance	2004 data						
Average Wait and Transfer Time (min)							
Percent of Passengers Requiring a Transfer							
Customer Perception of Wait Time and Transfer Time	44% of passengers rate frequency of service as good or very good (avg rating = 3.25 out of 5)						

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time (cont'd.)

	Pittsburgh	Pittsburgh	Pittsburgh	Sacramento	San Jose	Halifax
	East Busway	South Busway	West Busway	E-Bus	Rapid 522	MetroLink
Stations						
Location	Off-street	Off-street	Off-street	On- and off-street	On- and off-street	On- and off-street
ITS						
Automatic Vehicle Location (AVL)				None	GPS	AVL
Automatic Scheduling and Dispatch				None	Trapeze	None
Passenger Information				On vehicle	Automated next stop announcements, automated trip planning through website	Real-time display trip planning
Service Plan						
Route Structure				Replaced limited service route	Overlaps local route, headway based	Overlaps route
Peak Service Frequency (min)	0.58		1.33	15	15	10
Method of Schedule Control	Schedule	Schedule	Schedule		Headway	
Performance	2004 data					
Average Wait and Transfer Time (min)				7 for bus to rail/rail to bus		
Percent of Passengers Requiring a Transfer					22-29%	7%
Customer Perception of Wait Time and Transfer Time	78% of passengers perceived reduced wait time; 52% of passengers reported that transferring had gotten easier due to high frequency of EBA route					

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time (cont'd.)

	Ottawa Transitway			York		Bogotá	Guayaquil	Pereira
	95	96	97	VIVA Blue	VIVA Purple	Transmilenio	Metrovia	Megabus
Stations								
Location	On- and off-street	On- and off-street	On- and off-street	On- and off-street	On- and off-street	Off-street	Off-street	Off-street
ITS								
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	AVL-equipped	AVL-equipped	Loop detectors, station sensors	On-board transponders	On-board transponders
Automatic Scheduling and Dispatch	Yes	Yes	Yes	Yes	Yes			
Passenger Information	Yes	Yes	Yes	VMS at stops and on-board	VMS at stops and on-board	Nextbus displays at stations	Nextbus displays at stations	Nextbus displays at stations
Service Plan								
Route Structure				Overlays locals	Overlays locals	Replaced existing privately-operated routes	Replaced existing privately-operated routes	Replaced existing privately-operated routes
Peak Service Frequency (min)	3-4	3-6	12	5	10	1-3	4-6	3-5
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule			
Performance								
Average Wait and Transfer Time (min)				6:30	6:30			
Percent of Passengers Requiring a Transfer	40% for system	40% for system	40% for system	25%	25%			
Customer Perception of Wait Time and Transfer Time								

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time (cont'd.)

	Amsterdam	Caen	Edinburgh	Eindhoven	Leeds	London	Rouen	Utrecht
	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus	Crawley	TEOR	Busway
Stations								
Location		On- and off-street	On- and off-street	On- and off-street	On- and off-street	On- and off-street	On- and off-street	On- and off-street
ITS								
Automatic Vehicle Location (AVL)			GPS					
Automatic Scheduling and Dispatch			Yes					
Passenger Information	Real-time stop information, timetabled	Real-time at station/stop, online journey planner and timetable	Real-time, at station/stop, SMS	Real-time stop information, timetabled	Real-time, at station/stop, SMS	Timetable at station/stop	Real-time stop information, timetable	Real-time stop information, timetable
Service Plan								
Route Structure	New city orbital BRT link with intermodal links	Two routes overlapping in core area providing high frequency in downtown and Y pattern coverage north/south of downtown	Single radial route linking periphery to downtown	Two radial routes overlapping in central area, linking downtown with periphery and airport	Two radial routes linking periphery to downtown	2 north-south overlapping routes, LInks downtown to employment areas to north (Gatwick) and south	Three radial routes overlapping in central area, linking downtown with hospital, universities and peripheral areas	Three radial routes linking downtown to periphery
Peak Service Frequency (min)	7.5-8	3-6 (where routes overlap)	3	8	2-8	10	3	2-4
Method of Schedule Control								
Performance								
Average Wait and Transfer Time (min)								
Percent of Passengers Requiring a Transfer								
Customer Perception of Wait Time and Transfer Time								

Exhibit 3-10: BRT Elements by System and Wait Time and Transfer Time (cont'd.)

	Adelaide	Brisbane		Sydney			Beijing	Kunming
	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Busway Network
Stations								
Location	Off-street	Off-street	Off-street	On- and off-street	Off-street	On- and off-street	Off-street	
ITS								
Automatic Vehicle Location (AVL)		GPS	GPS	Loop detectors			Yes	
Automatic Scheduling and Dispatch								
Passenger Information	No real-time at station/stop or on vehicle; city web site has trip itinerary planning	Real-time Info at stations	Real-time Info at stations	Real-time Info at stations	Real-time Info at terminus stations only	Real-time at stations and on vehicles	Currently being implemented	
Service Plan								
Route Structure	BRT network replaced local routes	BRT network, overlaid on existing local routes	BRT network replaced local routes	BRT network, overlaid on existing local routes	BRT network, overlaid on existing local routes	BRT network, overlaid on existing local routes	BRT network replacing existing routes in busiest corridors	BRT network replacing existing routes in busiest corridors
Peak Service Frequency (min)	1.1	16-sec headway at Buranda Station	4.6	10.0	8.6	4.0		
Method of Schedule Control								
Performance								
Average Wait and Transfer Time (min)								Down 59%
Percent of Passengers Requiring a Transfer	Low	Low	Low					
Customer Perception of Wait Time and Transfer Time								

RELIABILITY

Passengers are attracted to trips with short travel times, but they are more likely to continue using the service if they can depend on consistent levels of service. Reliability is affected by a number of sources of uncertainty, including traffic conditions, route length, recovery times built into the route schedules, number of stops, evenness of passenger demand, and the unpredictable use of wheelchair lifts/ramps and vehicle breakdowns due to unforeseen mechanical or non-mechanical problems.

Some of these factors are not within the direct control of the transit operator. Nevertheless, there are many features of BRT that improve reliability. In this discussion, the focus is on three main aspects of reliability—running time reliability, station dwell time reliability, and service reliability. Running time reliability and station dwell time reliability relate to a system's ability to meet a schedule or a specified travel time consistently, while service reliability captures the characteristics of the system that contribute to passengers perception of service availability and dependability.

Running Time Reliability

Description of Running Time Reliability

Running time reliability is the ability of a BRT service to maintain a consistently high speed to provide customers with consistent travel times.

Effects of BRT Elements on Running Time Reliability

Running way characteristics that contribute to reductions in running way travel time can also improve reliability.

Running Way—Running Way Type (Right-of-Way Location, Level of Running Way Priority)
Running way segregation reduces the number of unpredictable delays at intersections and along the running way, reducing the variability of the trip times. Reliability is greatest for fully grade-separated exclusive running ways since complete segregation effectively eliminates conditions that cause delay (traffic congestion, intersection signals, turning movements, and exposure to accidents).

Stations—Passing Capability
Designing stations so vehicles can pass each other allows vehicles that have already completed loading at the station or that serve routes that bypass the station to continue on their journeys and maintain their schedule without delay.
ITS—Transit Vehicle Prioritization
Transit signal priority systems allow a BRT vehicle to maintain its schedule by giving those BRT vehicles that are behind schedule extra green time.
Signal timing/phasing can give more overall green time to BRT vehicles operating at peak times in the peak direction.
Station and lane-access control reduce the number of illegal vehicles operating on the facility by restricting access to facilities and stations to authorized BRT vehicles.
ITS—Intelligent Vehicle Systems
Collision warning, **lane assist**, and **precision docking** give the BRT vehicle operator added insurance to operate at consistent speeds regardless of traffic condition, thereby ensuring overall system reliability by maintaining a schedule.
ITS—Operations Management
Automatic vehicle location, **automated scheduling and dispatch**, and **vehicle component monitoring** systems enable a central dispatcher to know exactly what is happening to address the situation as needed. If there is an incident, such as a mechanical failure, an accident, or congestion, a central dispatcher can address problems quickly and efficiently, helping ensure the reliability of the service.
Service and Operations Plan—Station Spacing
Spacing stations further apart improves reliability for the same reasons that it improves running travel time:
Significant distances between stations allow vehicles to travel at a predictable, high speed for longer periods of time.
Serving fewer stations concentrates demand at each station, reducing the opportunities for variation due to starting and stopping and loading and unloading.
Service and Operations Plan—Route Length
Running time reliability is more possible with shorter route lengths, especially for BRT systems that have minimal running way segregation.

Performance of Existing Systems

The experience with documenting direct impacts on reliability is limited. Traditionally, transit planners have focused on other measures of performance. Increasingly, researchers are now focusing on reliability as a significant factor in attracting customers. This section presents profiles of systems that are good illustrations of achieving reliability and a summary of BRT systems' characteristics that affect reliability with available performance data.

System Performance Profiles

Orange Line, Los Angeles

A 2007 study that compared the end-to-end travel time performance of the Orange Line to Metro Rapid's Ventura Line found that the dedicated guideway provided greater travel time reliability. The Orange Line runs along a 14-mile dedicated guideway, while the Ventura Line operates for 16.4 miles in mixed traffic. The Orange Line also features near-level boarding and off-board fare collection with multiple-door bus entry; the Metro Rapid Venture Line serves conventional level curbside bus stops and employs on-board fare collection. Both lines have traffic signals at cross streets. This study found that, as of 2006, average travel times for the Orange Line were 41 minutes eastbound and 50 minutes westbound, which was roughly comparable to the Metro Rapid Ventura Line's travel times. However, the Orange Line showed the same travel times for each direction in AM and PM peak periods. The Ventura Line travel times revealed large variability: AM westbound travel was 44 minutes, compared to 50 minutes in the afternoon; AM eastbound travel was 45 minutes, compared to 59 minutes in the afternoon. It appears that, because the Orange Line has its own right-of-way, travel times are more consistent than with Metro Rapid, as Metro Rapid travel times can be significantly affected by traffic conditions on arterial streets (Vincent and Callaghan 2004).

Wilshire Boulevard Dedicated Lane Demonstration Project, Los Angeles

The Wilshire Boulevard Dedicated Lane Demonstration Project was implemented in Spring 2004 during peak-periods (weekdays from 7:00 - 9:00 AM and 4:00 - 7:00 PM). Curb bus-only lanes are in effect in each direction of traffic on a 0.9-mile section of Wilshire Boulevard between Federal and Centinela avenues in West Los Angeles. Prior to bus lane implementation, curbside parking was allowed, and Los Angeles Metro buses operated in mixed-flow traffic during the peak periods.

Four days of on-board survey data (two days before project implementation, two days after implementation) and two months of loop detector data (one month before, one month after) were analyzed to assess the demonstration project's impact on bus running times in the segment. Running times were reduced during each hour of the peak period in both directions of traffic by an average of about seven percent. Running time reliability (i.e., the range between the 5th and 95th percentiles of travel time observations) also improved in nearly all times of the day, by an average of about 17 percent.

Various Operations Management Applications (Non-BRT)

Two technologies that have the largest impact on system reliability include automatic vehicle location systems and transit signal priority. A vehicle location system can reduce bus bunching, improve bus spacing, and improve schedule adherence, resulting in increased system reliability. In Portland, Oregon, bus spacing improved 36 percent after Tri-Met used vehicle location data to adjust headway and run times. Also, on-time performance improved from 70 to 83 percent for one route once vehicle location data were available. Baltimore demonstrated a 23 percent increase in on-time performance for those buses equipped with vehicle location technology. In Kansas City, Missouri, on-time performance improved from 80 to 90 percent, with a 21 percent reduction in late buses and a 12 percent reduction in early buses after implementing a vehicle location system.

Just as transit signal priority reduces overall travel time, it also can improve system reliability by reducing vehicle delay and stops. In Phoenix, TSP reduced red-light delay by 16 percent. However, overall trip times were not reduced since bus operators operated more slowly to maintain operating schedules and to avoid arriving at time points early. This is a case where policy decisions impact the effectiveness of a technology and must be taken into account in the operation of a BRT system. An evaluation of the Toronto TSP system demonstrated a 32 to 50 percent reduction in signal delay for various bus routes.

BRT Elements by System and Running Time Reliability

Exhibit 3-11 provides a summary of running time reliability performance of BRT systems in 35 cities. The performance indicators developed to measure running time reliability include:

- Ratio of Minimum to Maximum Travel Time - the travel time differential between peak and non-peak travel times derived by dividing peak hour travel time by non-peak travel time; the higher the ratio, the greater the impact of peak hour traffic conditions on end-to-end travel times.
- Running Time Reliability (Coefficient of Variation) - the standard deviation of running time divided by the mean (average) running time.

- ✧ Survey of Customer Perception of Reliability - provided if cities have conducted customer satisfaction surveys.

Running time reliability describes the ability of a BRT system to maintain a consistently high speed. The system characteristics that impact running time—including running way segregation, ITS, and station spacing - also affect running time reliability.

Exhibit 3-11 includes running time reliability performance indicators for 40 BRT routes or lines in 22 cities (several cities operate multiple systems or lines). The key performance indicator in this table is Ratio of Maximum Time to Minimum Time. As noted above, this figure is determined by dividing the peak-hour end-to-end travel time by the non-peak end-to-end travel time. (As with the running time analysis, it is important to keep in mind that end-to-end travel time data will reflect station dwell times as well as running way travel time.) Systems with a ratio of 1.00 indicate that travel times are not impacted by prevailing traffic conditions and can maintain high and consistent level of performance throughout the service day. A ratio higher than 1:00 indicates that peak travel times are longer than non-peak, and the higher the ratio, the more variable the travel time.

Not surprisingly, the ratio is typically lower for BRT systems that operate along dedicated or exclusive lanes than for those systems that operate within a mixed-flow environment. Exhibit 3-11 shows that segregating BRT service from mixed-flow traffic, which is subject to deteriorating levels-of-service during peak hours, allows the service to sustain a higher and more consistent level of performance over the entire service span. Almost all of the systems that operate on a segregated running way have a ratio of 1.0 to 1.2. For systems that operate along mixed-flow lanes, this ratio was typically higher, particularly in regions suffering from heavy local traffic conditions. For example, three of the highest ratios are the Garfield Express (1.42) in Chicago, the VIVA Blue Line (1.4) in York, Canada, and the Boston Silver Line Washington Street service (1.5). All three are systems that operate on major arterial roads that are subject to recurring peak-hour traffic congestion.

The correlation between running way segregation and reliability is not nearly as strong as it is for travel time performance. For example, two of the best performing lines are the VIVA Purple Line (1.0) and the Kansas City MAX (1.1). Both operate in mixed traffic but incorporate transit signal priority and wider station spacing than typical local service. In addition, there is variability within systems that is not clearly explained by this data set. For example, the Ottawa 97 line has a much lower level of reliability than the 95 and 96 lines, although they share the same BRT elements.

Another important difference between running time performance and reliability performance is that segregated running ways with at-grade intersection crossings do not appear to suffer a reliability penalty. Two of the systems with at-grade crossings –Miami's South Dade Busway, and the Los Angeles Orange Line—offer some of the best reliability ratios.

Beyond the running way segregation and priority, there is no clear correlation between any particular element and reliability. Elements such as station spacing, route length, and ITS features are associated with varying levels of reliability. There may be two general conclusions to draw from this. First, it seems likely that it is the combination of BRT elements that impact reliability and not any one in isolation. Second, the impacts may be the result of some other factor not being reflected in this particular data set. For example, a likely factor is the level of traffic congestion experienced in a mixed running way environment. Boston's Washington Street line operates for a short time in an extremely congested area of the Central Business District with very narrow streets; by contrast, the VIVA Purple Line operates in wide streets in a suburban environment. These factors may play a larger role in the travel time variability than the simple fact of mixed lane operation.

In addition to running time variability, a few cities reported the results of surveys measuring passenger perceptions of reliability. Overall, the results of these surveys were positive. Riders of BRT lines in Los Angeles, Sacramento, Ottawa, the York Region, Bogotá, Adelaide, and Brisbane gave their city's BRT service high marks for reliability. The results for the Boston Silver Line were mixed. The Waterfront service was rated highly, with 67 percent of passengers rating it above average or excellent in terms of reliability. However, in a 2005 survey, the Washington Street service only received high marks from 35 percent of riders. This was a major drop from a 2003 survey which found 65 percent of riders rating reliability as above average or better. An FTA evaluation of the Silver Line reports that this drop in passenger satisfaction was due to pilot tests of new on-board electronic fare boxes, which resulted in a significant increase in boarding delays and travel times.

Exhibit 3-11: BRT Elements by System and Running Time Reliability

	Albuquerque	Boston Silver Line			Chicago			Cleveland
	Rapid Ride	Washington Street	Waterfront SL1 – Airport	Waterfront SL2 - BMIP	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Running Way (mi)								
On-Street Mixed Lanes	13.1	0.2	3.5	1.2	18.3	9.0	9.4	2.7
On-Street Exclusive Bus Lanes	0.7	2.2						4.4
Off-Street Mixed Lanes								
Off-Street Reserved Lanes								
At-Grade Transitways								
Grade-Separated Transitways			1.0	1.0				
Queue Jumpers	No	No	No	No	No	No	No	No
Station								
Passing Capability	No	No	No	No	No	No	No	No
ITS								
Transit Vehicle Prioritization	TSP	TSP						
Intelligent Vehicle Systems			None	none				Precision docking
Automatic Vehicle Location (AVL)			GPS, dead reckoning in tunnel	GPS, dead reckoning in tunnel				
Automatic Scheduling and Dispatch			CAD	CAD				
Vehicle Component Monitoring System								
Service Plan								
Route Length	13.8	2.4	4.5	2.2	18.3	9.0	9.4	7.1
Average Station Spacing (mi)	0.87	0.22	0.56	0.22	0.47	0.50	0.56	0.42
Performance					2004 data	2004 data	2004 data	
Ratio of Maximum to Minimum Running Time	1.2	1.5			1.3	1.19	1.42	
Running Time Reliability (Coefficient of Variation)	0.075		10-20%	10-35%				
Survey of Customer Perception of Reliability		35% rated good or excellent	67% rated good or excellent	67% rated good or excellent				

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Eugene	Honolulu	Honolulu	Honolulu	Kansas City	Las Vegas	Los Angeles	Los Angeles
	EmX	City Express A	City Express B	County Express C	MAX	North Las Vegas MAX	Orange Line	Metro Rapid (All Routes)
Running Way (mi)								
On-Street Mixed Lanes	1.4	19.0	8.0	18	6.0	2.9	1.0	229
On-Street Exclusive Bus Lanes	2.6					4.7		
Off-Street Mixed Lanes				3.5				
Off-Street Reserved Lanes				17.5				
At-Grade Transitways							13.5	
Grade-Separated Transitways								
Queue Jumpers	Yes	No			No			
Station								
Passing Capability	No				No		Passing lane at each in-line station	
ITS								
Transit Vehicle Prioritization	Yes				Yes	TSP		TSP
Intelligent Vehicle Systems	No					Precision docking		
Automatic Vehicle Location (AVL)	GSP	GPS	GPS	GPS	GPS	Orbital	GPS, loop detectors	GPS, loop detectors
Automatic Scheduling and Dispatch	CAD					CAD/AVL		
Vehicle Component Monitoring System						Yes	None	None
Service Plan								
Route Length	4.0	19.0	8.0	39.0	6.0	7.5	14.5	229.5
Average Station Spacing (mi)	0.44	0.56	0.29	0.98	0.30	0.75	1.12	0.71
Performance								
Ratio of Maximum to Minimum Running Time	2.2	1.3	1.2		1.1	1.1	1.1	
Running Time Reliability (Coefficient of Variation)								
Survey of Customer Perception of Reliability							Yes, very good	Yes, very good

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Miami	Oakland	Orlando	Phoenix	Phoenix	Phoenix	Phoenix
	Busway	Rapid San Pablo Corridor	LYMMO	RAPID I-10 East	RAPID I-10 West	RAPID SR-51	RAPID I-17
Running Way (mi)							
On-Street Mixed Lanes		14.0		6.5	4.8	12.3	8.0
On-Street Exclusive Bus Lanes							
Off-Street Mixed Lanes							
Off-Street Reserved Lanes				14.0	8.0	10.3	11.5
At-Grade Transitways	20.0		3.0				
Grade-Separated Transitways							
Queue Jumpers							
Station							
Passing Capability	Off-street	On-street	Off-street	On-street	On-street	On-street	On-street
ITS							
Transit Vehicle Prioritization		TSP		TSP (1 signal)	TSP (1 signal)	TSP (1 signal)	TSP (1 signal)
Intelligent Vehicle Systems				Collision warning	Collision warning	Collision warning	Collision warning
Automatic Vehicle Location (AVL)	AVL	GPS	AVL / wi-fi	Orbital	Orbital	Orbital	Orbital
Automatic Scheduling and Dispatch	CAD	Yes		Yes	Yes	Yes	Yes
Vehicle Component Monitoring System	Yes						
Service Plan							
Route Length	8.0	14.0	3.0	20.5	12.8	22.5	19.5
Average Station Spacing (mi)	0.71	0.56	0.30	1.86	1.59	2.05	1.63
Performance	2004 data	2004 data					
Ratio of Maximum to Minimum Running Time	1.0 (original 8.5 segment)	1.2					
Running Time Reliability (Coefficient of Variation)				0.9 (90%)	1 (100%)	1 (100%)	1 (100%)
Survey of Customer Perception of Reliability							

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Pittsburgh	Pittsburgh	Pittsburgh	Sacramento	San Jose	Halifax
	East Busway	South Busway	West Busway	E-Bus	Rapid 522	MetroLink
Running Way (mi)						
On-Street Mixed Lanes	0.4		0.4	8	25	12.1
On-Street Exclusive Bus Lanes						0.5
Off-Street Mixed Lanes						10.6
Off-Street Reserved Lanes				4		
At-Grade Transitways						
Grade-Separated Transitways	8.7	4.3	4.6			
Queue Jumpers						
Station						
Passing Capability	Passing lanes	Passing lanes	Passing lanes			
ITS						
Transit Vehicle Prioritization			TSP	TSP	TSP	TSP
Intelligent Vehicle Systems	Collision warning	Collision warning	Collision warning			
Automatic Vehicle Location (AVL)					GPS	Yes
Automatic Scheduling and Dispatch					Trapeze	
Vehicle Component Monitoring System						
Service Plan						
Route Length	9.1	4.3	5.0	12.0	25.0	23.2
Average Station Spacing (mi)	1.14	0.54	0.83	0.47	0.86	3.3
Performance	2004 data	2004 data	2004 data			
Ratio of Maximum to Minimum Running Time	1.1	1.0	1.2	1.3		
Running Time Reliability (Coefficient of Variation)				0.85		
Survey of Customer Perception of Reliability				Yes	Yes	

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Pittsburgh			York		Bogotá	Guayaquil
	95	96	97	VIVA Blue	VIVA Purple	Transmilenio	Metrovia
Running Way (mi)							
On-Street Mixed Lanes	2.1	2.1	2.1	20.3	17.1		
On-Street Exclusive Bus Lanes				Some bus-only intersection lanes	Some bus-only intersection lanes		
Off-Street Mixed Lanes	3.2	13.1	5.2				
Off-Street Reserved Lanes	8.7	3.8	1.2				
At-Grade Transitways	12.0	8.2	9.8			52.0	10.0
Grade-Separated Transitways							
Queue Jumpers							
Station							
Passing Capability	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	
ITS							
Transit Vehicle Prioritization	TSP	TSP	TSP	TSP	TSP		
Intelligent Vehicle Systems							
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	AVL-equipped	AVL-equipped	Loop detectors, station sensors	On-board transponders
Automatic Scheduling and Dispatch	Yes	Yes	Yes	Yes	Yes		
Vehicle Component Monitoring System	Under development	Under development	Under development	Oil temp, oil pressure, engine temp reported to control centre	Oil temp, oil pressure, engine temp reported to control centre		
Service Plan							
Route Length	25.9	27.2	18.4	20.3	17.1	52.0	10.0
Average Station Spacing (mi)	0.95	1.20	0.60	1.10	1.00		
Performance							
Ratio of Maximum to Minimum Running Time	1.0	1.1	1.4	1.4	1.0		
Running Time Reliability (Coefficient of Variation)	4.12 - 4.21	4.46 - 4.47	3.63 - 4.24				
Survey of Customer Perception of Reliability	Yes, 67% of riders call service reliable	Yes, 67% of riders call service reliable	Yes, 67% of riders call service reliable	Yes, rated excellent	Yes, rated excellent	Yes	

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Pereira	Amsterdam	Caen	Edinburgh	Eindhoven	Leeds	London
	Megabus	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus	Crawley
Running Way (mi)							
On-Street Mixed Lanes		1.9		1.9	2.2		11.2
On-Street Exclusive Bus Lanes		6.2	9.2	2.2		3.8	3.7
Off-Street Mixed Lanes		2.5					
Off-Street Reserved Lanes							
At-Grade Transitways	17.0	14.9	0.1	0.9	7.2	2.2	0.9
Grade-Separated Transitways							
Queue Jumpers							
Station							
Passing Capability							
ITS							
Transit Vehicle Prioritization					TSP	TSP	
Intelligent Vehicle Systems		Precision docking	Precision docking	Precision docking	Not being used	Precision docking	Precision docking
Automatic Vehicle Location (AVL)	On-board transponders			GPS			
Automatic Scheduling and Dispatch				Yes			
Vehicle Component Monitoring System							
Service Plan							
Route Length	17.0	25.5	9.3	5.0	9.4	6.0	15.8
Average Station Spacing (mi)		0.9-1.2	0.2-0.25	0.2-0.25	0.34		0.25
Performance							
Ratio of Maximum to Minimum Running Time				11.0			
Running Time Reliability (Coefficient of Variation)							
Survey of Customer Perception of Reliability							

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Rouen	Utrecht	Adelaide	Brisbane		Sydney	
	TEOR	Busway	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea
Running Way (mi)							
On-Street Mixed Lanes	8.7	3.5					
On-Street Exclusive Bus Lanes		2.0					
Off-Street Mixed Lanes							
Off-Street Reserved Lanes							
At-Grade Transitways	14.9	4.8					4.4
Grade-Separated Transitways			7.46	10.3	1.7	13.0	
Queue Jumpers							
Station							
Passing Capability			Passing at interchanges	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts
ITS							
Transit Vehicle Prioritization	TSP	TSP	Passive priority			TSP	
Intelligent Vehicle Systems	Precision docking		Precision docking				
Automatic Vehicle Location (AVL)				GPS	GPS	Loop detectors	
Automatic Scheduling and Dispatch							
Vehicle Component Monitoring System							
Service Plan							
Route Length	23.6	10.3	7.5	10.3	1.7	19.0	4.7
Average Station Spacing (mi)	0.33		3.10	1.00	0.41	0.54	0.42
Performance							
Ratio of Maximum to Minimum Running Time			1.3	1.1	1.1	1.1	1.2
Running Time Reliability (Coefficient of Variation)							
Survey of Customer Perception of Reliability			Yes	Yes	Yes	Yes	

Exhibit 3-11: BRT Elements by System and Running Time Reliability (cont'd.)

	Sydney	Beijing	Kunming
	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Busway Network
Running Way (mi)			
On-Street Mixed Lanes			
On-Street Exclusive Bus Lanes			
Off-Street Mixed Lanes			
Off-Street Reserved Lanes			24.9
At-Grade Transitways	8.7		
Grade-Separated Transitways		8.1	
Queue Jumpers			
Station			
Passing Capability	Bus pullouts	Multiple lanes	
ITS			
Transit Vehicle Prioritization		TSP	
Intelligent Vehicle Systems			
Automatic Vehicle Location (AVL)		Yes	
Automatic Scheduling and Dispatch			
Vehicle Component Monitoring System			
Service Plan			
Route Length	10.6	10.3	24.9
Average Station Spacing (mi)	0.50		
Performance			
Ratio of Maximum to Minimum Running Time	1.0	38%	Speeds up 68%
Running Time Reliability (Coefficient of Variation)			
Survey of Customer Perception of Reliability			

Station Dwell Time Reliability

Description of Station Dwell Time Reliability

Station dwell time reliability represents the ability for BRT vehicles to consistently load passengers within a certain dwell time and to minimize the amount of time spent at the station. Passenger loads can vary significantly throughout the day and even within each peak period. Incorporating BRT elements to accommodate this significant variation without impacting travel times can improve reliability. This is especially important, since BRT systems serve corridors and locations with high transit demand. Lengthy dwell times can affect the overall perception of reliability beyond the actual time spent (*The Role of Transit Amenities and Vehicle Characteristics in Building Transit Ridership*, p. 27).

Effects of BRT Elements on Station Dwell Time Reliability

Each of the BRT element options that help make station dwell times more reliable is described below.

Stations—Curb Design

Level platforms or **raised curbs** facilitate consistent station dwell times by reducing the need to step up to the vehicle.

Stations—Platform Layout

Extended platforms allow for more than one vehicle to board at a time and reduce the amount of time that vehicles must wait in queues to load passengers.

Vehicles—Vehicle Configuration

To comply with the Americans with Disabilities Act (ADA), a majority of vehicles now being produced in the U.S. have low floors at the doors to facilitate boarding and alighting. Low-floor vehicles not only speed boarding for general (ambulatory) passengers, they contribute to the reliability of station dwell times when integrated well with station or stop design.

Vehicles—Passenger Circulation Enhancement

In the same way that passenger circulation enhancements reduce dwell time, they also reduce dwell time variability and enhance reliability. The most dramatic of the passenger circulation enhancements that promote reliability is **enhanced wheelchair securement.**

Fare Collection—Fare Collection Process

Off-board fare collection processes **(barrier-enforced pre-payment systems** or **proof-of-payment systems)** eliminate the need for passengers to pay or show passes as they board the vehicle, allowing for multiple-door boarding and reducing the variability in the time it takes customers to either produce the required money or the required pass. **On-board conductor validation** has a similar effect but with lower magnitude.

Fare Collection—Fare Media and Payment Options

Electronic fare collection systems and **pre-paid instruments** can make dwell times more reliable, primarily by reducing the need for boarding passengers to search for exact change and by reducing transaction times.

ITS—Intelligent Vehicle Systems

Precision docking systems enable a BRT vehicle operator to precisely place the BRT vehicle a certain distance from the station platform to eliminate the need for wheelchair ramps.

ITS—Operations Management

Transit vehicle tracking enables a central dispatcher to know exactly where a BRT vehicle is and address problems that may arise while the BRT vehicle is at a station.

Service and Operations Plan—Service Frequency

Increasing service frequency reduces the number of passengers that can accumulate at the station, reducing the time associated with loading them.

Service and Operations Plan—Method of Schedule Control

Headway-based schedule control makes headways more regular, ensuring even loads and loading times.

Performance of Existing Systems

Research Summary

A study of boarding times for ambulatory passengers reported the times to be faster with low-floor buses, from 0.2 to 0.7 seconds. The average boarding time of wheelchair passengers was faster with the ramp than with a lift, 27.4 seconds versus 46.4 seconds. While these shorter boarding/alighting times had not resulted in increases in schedule speed at any of the transit agencies interviewed, some felt that the faster ramp operations made it easier to maintain schedule (dwell time reliability), particularly when multiple, unpredictable wheelchair boardings occurred during a run (King 1998).

Typical wheelchair lift cycle times, including the time required to secure the wheelchair inside the vehicle, are 60 to 200 seconds, while the ramps used in low-floor buses reduce the cycle times to 30 to 60 seconds (*Transit Capacity and Quality of Service Manual, 2nd Edition*).

Research shows that an emerging application to reduce station dwell times is the use of rear-facing positions for wheelchair securement on transit buses. Securement of wheelchairs on transit buses can take more than three minutes using conventional securement devices and with the assistance of an operator (Hardin and Foreman 2002). A rear-facing position for wheelchairs is being incorporated into vehicles at various transit agencies in Europe and Canada and at AC Transit in California. Sometimes, they are used in combination with more conventional forward-facing positions. A survey of six transit agencies in Canada suggests that dwell times can be less than one minute in cases of wheelchair loading with the use of rear-facing positions for wheelchairs (Rutenberg and Hemily 2003).

System Performance Profiles

EmX, Eugene

In January 2007, Lane Transit District (LTD) in Eugene, Oregon launched its first BRT service, the EmX Green Line. The four-mile Green Line uses dedicated busways and exclusive bus lanes, transit signal priority, enhanced stations, and high-capacity vehicles. The EmX replaced LTD's most popular local bus service. In the first few weeks following the EmX's launch, average weekday boardings rose by 70 percent, from 2,667 to 4,506. As of October 2007, average weekday boardings were up to 6,200. The EmX employs several features that help ensure short and consistent station dwell times. The service uses high-capacity vehicles with multiple-door boarding. Currently, the service is free, so there is no on-board fare collection to delay boarding. (LTD will implement off-board fare collection with its next EmX line.) LTD achieves "near-level" boarding through the use of raised platforms and, to mimimize horizontal gaps, the platforms have plastic striping along the platform edge that allow the drivers to pull in as close as possible without damaging the vehicle. Drivers also visually line up the vehicle front with EmX logos painted on the platforms to ensure consistent berthing spots. Finally, drivers must adhere to a strict schedule for passenger boarding at each station, closing doors promptly at the scheduled departure time. According to LTD, this has required a culture change for the drivers who are accustomed to a more "laid-back" approach to passenger boarding.

BRT Elements by System and Station Dwell Time Reliability

Exhibit 3-12 presents a summary of BRT elements that support dwell time reliability by system and the relevant performance indicator dwell time variability (Coefficient of Variation of Station Dwell Times).

The BRT elements that can improve reliability are the same as those that reduce dwell times. As noted in the section discussing dwell times, in the U.S., the most commonly-employed element affecting reliability is low-floor vehicles. Most U.S. systems are now using low-floor buses, which help ease boarding and ensure consistent dwell times. In addition, most U.S. BRT systems operate at headways no greater than 12 minutes at peak times. Shorter headways help reliability by reducing the number of passengers attempting to board at any particular schedule stop. Fewer U.S. systems use the other key factors—off-board fare collection, multiple-door boarding, and level or near-level boarding.

Only the Cleveland HealthLine, Eugene EmX, Las Vegas MAX, and Los Angeles Orange Line have incorporated level or near-level boarding, which further reduces boarding time, especially by allowing direct access for the mobility impaired. This is a key factor for dwell time reliability because, while the percentage of mobility-impaired passengers may be small, deploying a ramp or other accessibility device can take several minutes and require the attention of the driver. This will impact dwell time consistency more than it will impact overall dwell times.

These four U.S. systems also have implemented off-board fare collection, multiple-door boarding, and specialized BRT vehicles with wider aisles for improved passenger circulation. These features all contribute to dwell time reliability. Outside the U.S., it is much more common for cities to implement a "suite" of BRT elements designed to improve station dwell times.

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability

	Albuquerque	Boston Silver Line		Chicago			Cleavland
	Rapid Ride	Washington Street	Waterfront	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Stations							
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Level platform
Platform Layout (# vehicles accommodated)	1	1	1 above ground, 3 underground	1	1	1	1
Vehicles							
Configuration	Articulated	Stylized articulated	Articulated	Conventional standard	Stylized articulated	Articulated	Articulated
Floor Height	Low	Step low	Low	High	Low	Low	Low
Fare Collection							
Fare Collection Process	Pay on-board	Pay on-board	Barrier at 3 underground stations; others are Pay On-Board	Pay on-board	Pay on-board	Pay on-board	Off-board
Fare Media and Payment Options	Cash, paper	Cash, paper transfers, magnetic stripe, smart card	Cash, paper ticket, smart card	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe	
ITS							
Intelligent Vehicle Systems							
Service Plan							
Peak Service Frequency (min)	11	4	10	9	11	12	15
Method of Schedule Control		Schedule	Schedule	Schedule	Schedule	Schedule	Schedule
Performance							
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)							

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability (cont'd.)

	Eugene	Honolulu			Kansas City	Las Vegas	Los Angeles	Los Angeles
	EmX	City Express A	City Express B	County Express C	MAX	North Las Vegas MAX	Orange Line	Metro Rapid (All Routes)
Stations								
Curb Design	Raised curb	Standard curb	Standard curb	Standard curb		Raised curb	8" curb	Standard curb
Platform Layout (# vehicles accommodated)	1	1	1	1	1	1	3	1
Vehicles								
Configuration	Articulated	Articulated	Standard	Articulated	Stylized conventional	Stylized articulated	Stylized articulated	Stylized standard and articulated
Floor Height	Low	Low	High	Low	Low	Low	Low	Low floor
Fare Collection								
Fare Collection Process	None	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Proof-of-payment	Proof-of-payment	Pay on-board
Fare Media and Payment Options	None	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe	Cash, paper, magnetic stripe		Magnetic stripe	Tickets from TVM and standard paper passes	Cash and paper passes
ITS								
Intelligent Vehicle Systems						Precision Docking		-
Service Plan								
Peak Service Frequency (min)	10	15	15	30	9	12	4	2-10
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule	Headway		Headway
Performance								
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)								

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability (cont'd.)

	Miami	Oakland	Orlando	Phoenix	Phoenix	Phoenix	Phoenix
	Busway	Rapid San Pablo Corridor	LYMMO	RAPID I-10 East	RAPID I-10 West	RAPID SR-51	RAPID I-17
Stations							
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)	3	1	2	1	1	1	1
Vehicles							
Configuration	Conventional standard and minis	Stylized standard	Conventional standard	Stylized standard	Stylized standard	Stylized standard	Stylized standard
Floor Height	Step low	Step low	Low	Step low	Step low	Step low	Step low
Fare Collection							
Fare Collection Process	Pay on-board	Pay on-board	Free	Pay on-board	Pay on-board	Pay on-board	Pay on-board
Fare Media and Payment Options	Cash, paper, magnetic stripe	Cash, paper, smart card		Cash, paper	Cash, paper	Cash, paper	Cash, paper
ITS							
Intelligent Vehicle Systems				Collision warning	Collision warning	Collision warning	Collision warning
Service Plan							
Peak Service Frequency (min)	10	12	5	10	10	10	10
Method of Schedule Control	Schedule	Schedule	Headway	Schedule	Schedule	Schedule	Schedule
Performance							
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)							

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability (cont'd.)

	Pittsburgh East Busway	Pittsburgh South Busway	Pittsburgh West Busway	Sacramento E-Bus	San Jose Rapid 522	Halifax MetroLink
Stations						
Curb Design	Raised curb	Raised curb	Raised curb		Standard curb	Standard curb
Platform Layout (# vehicles accommodated)					2	2
Vehicles						
Configuration	Conventional standard and articulated	Conventional standard and articulated	Conventional standard and articulated	Standard	Stylized standard and articulated	Stylized standard
Floor Height	High	High	High	Low	Low	Low
Fare Collection						
Fare Collection Process	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay on-board
Fare Media and Payment Options	Cash, paper	Cash, paper	Cash, paper	Cash, passes	Cash, paper passes, (smart cards in development)	Cash, ticket, passes
ITS						
Intelligent Vehicle Systems	Collision warning	Collision warning	Collision warning			
Service Plan						
Peak Service Frequency (min)	0.58		1.33	15 min	15	10
Method of Schedule Control	Schedule	Schedule	Schedule		Headway	
Performance						
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)						

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability (cont'd.)

	Ottawa Transitway			York		Bogotá	Guayaquil	Pereira
	95	96	97	VIVA Blue	VIVA Purple	Transmilenio	Metrovia	Megabus
Stations								
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Level platform	Level Platform	Level Platform
Platform Layout (# vehicles accommodated)	3	3	3	1	1	2 - 5		1- 2
Vehicles								
Configuration	Articulated	Standard	Articulated	Articulated	Standard	Stylized articulated	Stylized standard and articulated	Stylized articulated
Floor Height	14.5 - 16" 11.5" kneeling	14.5 - 16" 11.5" kneeling	14.5 - 16" 11.5" kneeling	Low	Low	0.9 m		0.9 m
Fare Collection								
Fare Collection Process	Proof-of-payment	Proof-of-payment	Proof-of-payment	Proof-of-payment	Proof-of-payment	Barrier (verify at station entrances / exits)	Barrier	Barrier (verify at station entrances)
Fare Media and Payment Options	Cash, paper tickets, passes	Cash, paper tickets, passes	Cash, paper tickets, passes	Paper tickets, passes	Paper tickets, passes	Smart cards	Cash, smart cards	Smart cards
ITS								
Intelligent Vehicle Systems								
Service Plan								
Peak Service Frequency (min)	3-4	3-6	12	5	10	1-3	4-6	3-5
Method of Schedule Control	Schedule	Schedule	Schedule	Schedule	Schedule			
Performance								
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)								

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability (cont'd.)

	Amsterdam	Caen	Edinburgh	Eindhoven	Leeds	London	Rouen	Utrecht
	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus	Crawley	TEOR	Busway
Stations								
Curb Design	Level platform	Level platform	Level platform	Level platform	Level platform, raised curb	Standard curb	Level platform	Level platform
Platform Layout (# vehicles accommodated)								
Vehicles								
Configuration	Articulated	Bi-articulated	Standard single and double deck	Articulated,	Standard	Stylized articulated	Stylized standard and articulated	Stylized articulated
Floor Height	Low	Low	Low	Low	Low	Low	Low	Low
Fare Collection								
Fare Collection Process	Pay on-board or proof-of-payment	Pay on-board or proof-of-payment	Pay on-board or proof-of-payment	Proof-of-payment, pay on-board machine, no driver payment	Pay on-board	Pay on-board	Off-board	Pay on-board or proof-of-payment
Fare Media and Payment Options	Paper (Strippenkart)	Smart cards, magnetic tickets	Cash coin (exact change) or smart card	Paper (Strippenkart)	Cash and paper only	Cash	Magnetic stripe	Paper (Strippenkart)
ITS								
Intelligent Vehicle Systems	Precision docking	Precision docking	Precision docking	Not being used	Precision docking	Precision docking	Precision docking	
Service Plan								
Peak Service Frequency (min)	7.5 - 8	3-6 (where routes overlap)	3	8	2-8	10	3	2-4
Method of Schedule Control								
Performance								
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)								

Exhibit 3-12: BRT Elements by System and Station Dwell Time Reliability (cont'd.)

	Adelaide	Brisbane		Sydney			Beijing	Kunming
	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Busway network
Stations								
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Standard curb	Level platform	Standard curb
Platform Layout (# vehicles accommodated)	3- and 4-bus length	Standard 4 max 5	Standard 4 max 5	Standard 2 max 6	Standard 2 4 at termini			60 m platform length
Vehicles								
Configuration	Standard articulated, standard rigid	Standard rigid	Standard rigid	Standard rigid	Standard rigid	Standard rigid	Articulated	Standard
Floor Height	Step high, step low	Mainly step low, some step high	Mainly step low, some step high	Step low	Step high	Step high, step low	Low	High
Fare Collection								
Fare Collection Process	Pay on-board (80% pre-pay multi-rider ticket)	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay on-board	Pay attendants at station	Pay on-board
Fare Media and Payment Options	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, paper magnetic stripe	Cash, smart cards	Cash, IC cards
ITS								
Intelligent Vehicle Systems	Precision docking							
Service Plan								
Peak Service Frequency (min)	1.1	16-sec headway at Buranda Station	4.6	10.0	8.6	4.0		
Method of Schedule Control								
Performance								
Dwell Time Variability (Coefficient of Variation of Station Dwell Times)								

Service Reliability

Description of Service Reliability

Service reliability is a qualitative characteristic related to the ability of a transit operation to provide service consistent with its plans and policies and the expectations of its customers. Three aspects of a transit operation promote service reliability:

- **Availability of service options**—service can be so dense and frequent that a missed or delayed trip results in little degradation of service. Passengers have multiple choices that allow them to respond to unpredictability of their own schedules and behavior (e.g., the need to work late or go home during the middle of the day).
- **Ability to recover from service disruptions**—strategies to quickly respond to unpredictable delays and disruptions.
- **Availability of "contingency" resources**—having sufficient "back-up" permits operator to meet its service plan in the face of all the uncertainties that could affect it, e.g., driver illness, traffic, and other unforeseen events.

Effects of BRT Elements on Service Reliability

The characteristics of many BRT elements affect service reliability are discussed below.

Stations—Passing Capability

Stations with passing lanes, either through **bus pullouts** or **passing lanes at stations**, minimize the risk that delays or incidents affecting one BRT vehicle will result in delays to other vehicles along the line. Disabled vehicles can pull over to the side of the running way or a portion of the station platform while other vehicles are able to pass and still meet their service.

Stations—Platform Layout

Extended platforms allow for flexibility of operations in case a vehicle breaks down or experiences excessively long delays while loading at stations, provided that the running way through the station allows vehicles to pass.

ITS—Transit Vehicle Prioritization

Vehicle prioritization systems can help facilitate bringing a vehicle back to its scheduled position after a brief interruption or delay to service.

ITS—Operations Management

Operations management systems allow system managers to quickly address any incidents that may arise and disseminates that information to riders.

ITS—Passenger Information Systems

While **passenger information systems** do not enable greater service reliability, they allow for transit agencies and operations managers to communicate to passengers waiting for and currently using the service of any service changes or disruptions, thereby reducing the impacts of disruptions.

Service and Operations Plan—Service Frequency

High-frequency BRT systems (less than five minutes) can give passengers an impression that the service is available at any station without delay, even when headways and schedule adherence vary, as long as inordinate bunching (irregular spacing between vehicles) is avoided.

Service and Operations Plan—Service Span

Service that extends to the off-peak periods (mid-day, evening, and late night) and on weekends provides potential users with expanded options for making round trips. Expanded service spans make BRT systems dependable.

In addition to these BRT elements, an agency can improve service reliability through programs and business processes, such as:

- enhanced maintenance programs for vehicles and other elements
- fleet management to maintain higher spare ratios

Performance of Existing Systems

System Performance Profiles

VIVA, York Region, Ontario

The VIVA BRT service operates in the York Region of Ontario, just north of Toronto. It is a five-line network that operates in four suburban corridors designated for concentrated, high-density development. The VIVA is being built in phases, with Phase I launched in 2005, just three years after planning began. Phase I incorporates BRT elements that can be deployed relatively quickly, such as enhanced shelters, signal priority, stylized high-capacity buses, off-board fare collection, queue jumper lanes, and a distinct branding scheme. The buses run on mixed-traffic curbside lanes until dedicated lanes can be built in Phase II. To improve travel times and ensure service reliability, York Region Transit implemented transit signal priority and a vehicle tracking system. The buses are equipped with GPS units that allow the control center to monitor the buses, alert drivers to potential delays or problems, and activate the transit signal priority when buses are behind schedule. Signal priority can extend the green light or shorten the red cycle and is limited to one bus per intersection per 2.5 minutes in any direction.

O-Bahn Busway, Adelaide

The O-Bahn Busway in Adelaide, Australia is a 12km guided busway system to the northeastern suburbs (opened in 1986) that uses a mechanical track guidance system developed in Germany. Buses are steered automatically using horizontal guide wheels that engage raised concrete edges on the track. Vehicles travel at speeds of up to 100 km/hour serving three stations in the alignment. Travel times along the corridor decreased from 40 minutes to 25 minutes.

Several aspects of the system support maximum service reliability. The stations are designed such that the vehicles pull off the guided track and serve stations that can accommodate more than one vehicle. Vehicles are, therefore, never stationary on the track. This configuration ensures that the 18 bus routes that serve the route can operate without interference due to delays on each individual route. During the peak hour, an average headway of less than one minute is maintained (67 vehicles per hour). Braking ability on rubber-tired vehicles also allows safe operating distances of as little as 20 seconds between vehicles along the guided track (Passenger Transport Board 1999). In rare cases of vehicle breakdowns on the guideway, vehicle operators inform the Traffic Control Centre and alert oncoming vehicles with a hazard light. A special maintenance and recovery vehicle equipped with guide-wheels and able to travel in both directions is used to recover stranded vehicles and to maintain the track. While the guideway section is blocked, vehicles are diverted from the blocked section along parallel arterial streets to the next station, minimizing delays.

San Pablo Rapid, Oakland and Orange Line, Los Angeles

These two systems demonstrate that it is possible to achieve good reliability with very different BRT strategies. The 14-mile San Pablo Rapid operates in mixed traffic along the San Pablo Avenue Corridor, serving seven cities in Alameda and Contra Costa counties. AC Transit developed the Rapid to improve service quality for existing customers and attract new riders. This was achieved by adding relatively low-cost BRT elements: a headway-based schedule at 12-minute intervals, stops that are at least one-half mile apart, transit signal priority and queue jumpers, and real-time bus arrival information. It features conventional on-board fare collection and standard curb height boarding. The system cost $3.2 million to implement. Even though the buses operate in a mixed traffic arterial, the reported ratio of maximum to minimum travel time is 1.21. During peak hours, service reliability is maintained by use of additional vehicles (National Bus Rapid Transit Institute 2006).

The Orange Line reports a reliability ratio of 1.1, which is achieved through a very different BRT strategy. The Orange Line also runs for 14 miles but operates almost entirely in a dedicated busway. Because traffic signals at intersections are managed to minimize delay to cross-traffic through intersections, the service does not feature full transit signal priority, although it does benefit from signal synchronization. To help speed boarding, the system uses off-board fare collection and raised platforms at the stations. It is served by articulated vehicles that run at five- to six-minute headways at peak hours. The initial cost to build the Orange Line was $318 million. Ridership on the Orange Line is significantly higher than on the San Pablo Rapid, with the Orange Line averaging over 26,000 weekday boardings compared to the Rapid, which has around 6,000. These two systems demonstrate the variety of strategies that can be used to implement high-performing BRT service (Stanger 2007).

Tri-Met Automated Bus Dispatching, Portland (Non-BRT)

Portland, Oregon's Tri-Met is a pioneer in the development, implementation, and deployment of transit ITS systems. Its bus dispatch system (BDS) began implementation in 1997 and became fully operational in 1998. The main features of the BDS include GPS-based Automatic Vehicle Location (AVL), voice and data communications, an on-board computer and mobile data terminal, automatic passenger counters (partial), and a Computer-Aided Dispatch (CAD) operations control center.

After implementation of the BDS, there was noticeable improvement in both on-time performance and instances of severe bus-bunching. Overall, on-time performance increased from 61.4 to 67.2 percent of all trips, a 9.4 percent gain. The greatest improvement occurred in the AM peak period, with a 129 percent gain. There was also a noticeable reduction in headway variation and bus bunching. Bus bunching, which is represented by headways below 70 percent of their scheduled values, declined by 15 percent. For PM peak outbound trips, where any irregularities in service are exacerbated by the high rate of passenger arrivals causing boarding backups and delays, extreme instances of bus bunching (headway ratios < 10 percent of scheduled values) declined by 37 percent (Weatherford 2000).

Regional Transit District AVL and CAD System, Denver (Non-BRT)

The Denver, Colorado Regional Transit District (RTD) was one of the first systems in the nation to install a GPS-based AVL system and a CAD system throughout its operations. The RTD transit system covers 2,400 square miles and consists of about 1,335 vehicles, including 936 buses in fixed-route service, 27 buses in the 16th Street Mall, 175 paratransit vehicles, 17 light-rail vehicles, and 180 supervisor and maintenance vehicles. In 1993, the RTD began installation of an AVL system across its fleet developed by Westinghouse Wireless Solutions.

Since the AVL system was implemented, the transit system has provided the customers with higher quality of service (most noticeable after final system acceptance). As reported in a U.S. DOT evaluation, "RTD decreased the number of vehicles that arrived at stops early by 125 between 1992 and 1997. The number of vehicles that arrived late at stops decreased by 21 percent. These improvements are to a system that was already performing well, and outstanding considering the impact that inclement weather can have on on-time performance during winter." From 1992 to 1997, customer complaints per 100,000 boardings decreased by 26 percent, due in large part to the improved schedule adherence.

London Transport Countdown System (Non-BRT)

London was one of the first cities in the world to deploy a next-bus-arrival system at bus stops. The system, called Countdown, was piloted in 1992 on Route 18 of the London system and proved highly popular with passengers. Deployment continued by stages. As of March 2002, 1,473 Countdown signs had been installed and were operational. The installation of 2,400 signs was expected by March 2003 and 4,000 signs by 2005. The 4,000 signs will cover 25 percent of all stops and will benefit 60 percent of all passenger journeys (Schweiger 2003). While the Countdown system does not directly affect service reliability, it had a noticeable impact on passenger's perceptions. It was found that 64 percent of those surveyed regarding the system believed service reliability had improved after Countdown was implemented.

BRT Elements by System and Service Reliability

Since the frequency of incidents and the responses to them are seldom recorded and not available in an easily comparable format, it is difficult to present a consistent measure to compare service reliability across systems. For this reason, this section characterizes performance simply by listing the BRT elements that have an effect on service reliability.

Exhibit 3-13 presents those BRT elements that are most relevant to assessing service reliability for BRT systems in 35 cities worldwide. ITS features, especially transit signal priority and automated scheduling and dispatch, are probably the most important elements for achieving service reliability. A majority of U.S. BRT systems use vehicle tracking devices at a minimum, with slightly less than half using transit signal priority or automated scheduling. Outside the U.S., a majority of BRT systems use vehicle tracking and TSP. Vehicle component monitoring is also becoming increasingly common, both in the U.S. and around the world.

Exhibit 3-13: BRT Elements by System and Service Reliability

	Albuquerque	Boston Silver Line			Chicago			Cleveland
	Rapid Ride	Washington Street	Waterfront SL1 – Airport	Waterfront SL2 - BMIP	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Stations								
Platform Length (# vehicles accommodated)	1	1	1 above ground, 3 underground	1 above ground, 3 underground	1	1	1	1 40' + 1 60'
Passing Capability								No
ITS								
Transit Vehicle Prioritization	TSP	TSP - Green Extension, Red Truncation						TSP
Automatic Vehicle Location (AVL)	GPS	GPS	GPS, dead reckoning in tunnel	GPS, dead reckoning in tunnel				Yes
Automatic Scheduling and Dispatch		None	CAD	CAD				
Vehicle Component Monitoring System		AVM						
Passenger Information	At Station / On Vehicle LED Nextbus signs	VMS at Stations and in-vehicle	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements				Real time passenger info
Service Plan								
Span of Service	All day	All day	All day	All day	All day	All day	All day	All day
Peak Service Frequency (min)	11	4	10	10	9	12	11	5
Off-Peak Service Frequency (min)	11	12	10 - 30	15				15

Exhibit 3-13: BRT Elements by System and Service Reliability (cont'd.)

	Eugene	Honolulu	Honolulu	Honolulu	Kansas City	Las Vegas	Los Angeles	Los Angeles
	EmX	City Express A	City Express B	County Express C	MAX	North Las Vegas MAX	Orange Line	Metro Rapid (All Routes)
Stations								
Platform Length (# vehicles accommodated)	1	1	1	1	1	1	3 (200')	1
Passing Capability	No						Passing Lane provided at each in-line station	
ITS								
Transit Vehicle Prioritization	TSP				TSP	TSP	No	None
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	GPS	GPS	Orbital	GPS, Loop Detectors	GPS, Loop Detectors
Automatic Scheduling and Dispatch	CAD					CAD/AVL		
Vehicle Component Monitoring System							None	None
Passenger Information	Vehicle, Web	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations	Real-time at all stations, trip planning	Station, telephone, internet, on-vehicle electronic displays	Nextbus VMS	Nextbus VMS at stations, telephone, internet
Service Plan								
Span of Service		All day	All day	All day	All day	All day	All day	All day
Peak Service Frequency (min)	10	15	15	30	9	12	4	2-10
Off-Peak Service Frequency (min)	20-30	30	20	30	30	15	10	15-20

Exhibit 3-13: BRT Elements by System and Service Reliability (cont'd.)

	Miami	Oakland	Orlando	Phoenix	Phoenix	Phoenix	Phoenix	Los Angeles
	Busway	Rapid San Pablo Corridor	LYMMO	RAPID I-10 East	RAPID I-10 West	RAPID SR-51	RAPID I-17	Metro Rapid (All Routes)
Stations								
Platform Length (# vehicles accommodated)	3	1	2	1	1	1	1	1
Passing Capability	Bus pullouts			Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	
ITS								
Transit Vehicle Prioritization	No	TSP	TSP	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection	None
Automatic Vehicle Location (AVL)	AVL	GPS	AVL/Wi-Fi	Orbital	Orbital	Orbital	Orbital	GPS, Loop Detectors
Automatic Scheduling and Dispatch	CAD	Yes		Yes	Yes	Yes	Yes	
Vehicle Component Monitoring System	Yes							None
Passenger Information	Traveler information at stations and on vehicle	Real-time arrival at stations; traveler info on vehicle and via PDA	Traveler Information at stations and on vehicle; web-based	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info	Nextbus VMS at stations, telephone, internet
Service Plan								
Span of Service	All day	All day	All day	Weekday peak-hour only	Weekday peak-hour only	Weekday peak-hour only	Weekday peak-hour only	All day
Peak Service Frequency (min)	6	12	5	10	10	10	10	2-10
Off-Peak Service Frequency (min)		15	10-15					15-20

Exhibit 3-13: BRT Elements by System and Service Reliability (cont'd.)

	Pittsburgh	Pittsburgh	Pittsburgh	Sacramento	San Jose	Halifax
	East Busway	South Busway	West Busway	E-Bus	Rapid 522	MetroLink
Stations						
Platform Length (# vehicles accommodated)					2 (typically)	2
Passing Capability	Passing allowed	Passing allowed	Passing allowed	None		None
ITS						
Transit Vehicle Prioritization			Signal Priority (magnetic loop sensors)	TSP - Gn Ext	TSP - Green Extension, Red Truncation	TSP
Automatic Vehicle Location (AVL)				None	GPS	AVL
Automatic Scheduling and Dispatch				None	Trapeze	None
Vehicle Component Monitoring System				None	None	None
Passenger Information				On Vehicle	Automated next stop announcements, real-time info in development, automated trip planning through website	Real-time display, trip planning
Service Plan						
Span of Service	All day	All day	All day	All day	All day, Mon-Sat	2 routes all-day weekdays, 1 route peak-hour only
Peak Service Frequency (min)	0.58		1.33	15 min	15	10
Off-Peak Service Frequency (min)				20 min	15	30

Exhibit 3-13: BRT Elements by System and Service Reliability (cont'd.)

	Ottawa Transitway			York		Bogotá	Guayaquil	Pereira
	95	96	97	VIVA Blue	VIVA Purple	Transmilenio	Metrovia	Megabus
Stations								
Platform Length (# vehicles accommodated)				1	1	2 to 5		1 to 2
Passing Capability	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts	Bus pullouts at many stations; some lines more than 2 lanes	No passing	No passing
ITS								
Transit Vehicle Prioritization	TSP	TSP	TSP	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction			
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	AVL-equipped	AVL-equipped	Loop detectors, station sensors	On-board transponders	On-board transponders
Automatic Scheduling and Dispatch	Yes	Yes	Yes	Yes	Yes			
Vehicle Component Monitoring System	Under development	Under| development	Under development	Oil temp, oil pressure, engine temp reported to control centre	Oil temp, oil pressure, engine temp reported to control centre			
Passenger Information	Yes	Yes	Yes	VMS at stops and on-board	VMS at stops and on-board	Nextbus displays at stations	Nextbus displays at stations	Nextbus displays at stations
Service Plan								
Span of Service	All day	All day	All day	18 hours per day	18 hours per day	All day		All day
Peak Service Frequency (min)	3-4	3-6	12	5	10	1 - 3	4 - 6	3 - 5
Off-Peak Service Frequency (min)	30-34	30-35	30	15	15	10		10

Exhibit 3-13: BRT Elements by System and Service Reliability (cont'd.)

	Amsterdam	Caen	Edinburgh	Eindhoven	Leeds	London	Rouen	Utrecht
	Zuidtangent	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus	Crawley	TEOR	Busway
Stations								
Platform Length (# vehicles accommodated)								
Passing Capability					No passing in guideway segments			
ITS								
Transit Vehicle Prioritization	RTSP	Signal priority - automatic	TSP	TSP	TSP in downtown areas		Signal priority- automatic and manual	Signal priority - automatic
Automatic Vehicle Location (AVL)			GPS					
Automatic Scheduling and Dispatch			Yes					
Vehicle Component Monitoring System								
Passenger Information	Real-time stop information, timetable	Real-time at station/stop, online-journey planner and timetable	Real-time, at station/ stop, SMS	Real-time stop information, timetable	Real-time, at station/stop, SMS	Timetable at station/stop	Real-time stop information, timetable	Real-time stop information, timetable
Service Plan								
Span of Service	All day	All day	All day	All day	All day	All day	All day	All day
Peak Service Frequency (min)	7.5 - 8	3-6 (where routes overlap)	3	8	2-8	10	3	2-4
Off-Peak Service Frequency (min)	10	10-15	10	10	2-8	10-20	4	3-7.5

Exhibit 3-13: BRT Elements by System and Service Reliability (cont'd.)

	Adelaide	Brisbane		Sydney			Beijing	Hangzhou	Kunming
	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Line B!	Busway network
Stations									
Platform Length (# vehicles accommodated)	Two stations have 3 bus length, one has 4-bus length	Standard 4 Max 5	Standard 4 Max 5	Standard 2 Max 6	Standard 2, 4 at termini			60 m	
Passing Capability	Passing at interchanges. busway is single 'track'	Bus pullouts at stations	Bus pullouts at stations	Bus pullouts at stations	Bus pullouts at stations	Bus pullouts at stations	Multiple lanes	Multiple lanes	None
ITS									
Transit Vehicle Prioritization	Passive priority (No active)			Signal pre-emption including green extension and early green			TSP	TSP	
Automatic Vehicle Location (AVL)	4 at termini	GPS	GPS	Loop detectors			Yes	Yes	
Automatic Scheduling and Dispatch									
Vehicle Component Monitoring System									
Passenger Information	City web site has trip planning	Real time info at stations	Real time info at stations	Real time info at stations	Real time info at terminus stations only	Real time info at terminus stations only	Rea time at stations and on vehicles	Rea time at stations and on vehicles	Currently being implemented
Service Plan									
Span of Service	Mix peak only and all day	Mainly all day	Mix peak only and all day	All day	All day	Most all day	All day	All day	All day
Peak Service Frequency (min)	1.1	16-sec headway at Buranda Station	4.6	10.0	8.6	4.0		3 - 4	
Off-Peak Service Frequency (min)	4	2	5	15	11.6	5			

IMAGE AND IDENTITY

The creation of an image and identity separate from local on-street bus operations is an important objective of BRT. Research has shown that if transit is to attract choice riders it must not only offer competitive travel times and high-quality service but also be complemented by an attractive image. Unfortunately, conventional bus service suffers from a severe image problem. Many people perceive the bus as an inferior way to travel when compared with the mobility, convenience, and personal freedom afforded by the automobile. Some of the most common negative views regarding bus service are that it is unreliable, time consuming, inaccessible, inconvenient, crowded, dirty, and unsafe (TCRP Report 63). These perceptions and their impact on the tangible response of patrons to BRT systems and BRT services highlight the need to focus on the image and identity of BRT.

This discussion focuses on two key aspects of image and identity: brand identity and contextual design. Brand identity is a concept that encompasses the broad range of attributes and the holistic "packaging" of a BRT system into an attractive product for transit patrons and potential transit patrons. The concept of contextual design represents the integration of physical design elements of the BRT system to convey a singular and attractive design aesthetic that communicates both the existence of the system and complements the physical urban environment.

Brand Identity

Description of Brand Identity

To increase its appeal to choice riders, an important objective for BRT is to establish an image and identity separate from local bus operations. The concept of brand identity captures both the qualities that affect identity - the consumer's overall perception of the style, aesthetics, and compatibility of the system elements and explicit branding- and marketing devices such as logos and color schemes. As such, brand identity includes not only things that passengers can see, but all things encompassing the senses, such as the chime of the bus arriving at the station, the slogan representing the system, or the comfort of the vehicle seats. Thus, brand identity is an important part of the image formation process within the public mind (Meenaghan 1995; Heffner et al. 2006).

The image of a BRT system determines how it is viewed among the set of other public transportation options. A well-crafted identity and the image of clean, modern, and efficient transportation can help achieve market differentiation and promote BRT as a premium, new "mode," which may help increase ridership, particularly by choice riders. A unified brand identity also can convey important customer information such as routing and stations served and help infrequent customers understand how to use the system (Levinson 2004).

Regarding identity and image, there are some noteworthy differences between products and services. BRT, like all forms of public transit, provides a service. Services, by their very nature, are largely intangible and experiential. They cannot be seen, felt, tasted, or touched before purchase and are therefore perceived as higher in risk than products (Onkvisit and Shaw 1989). Thus, an attractive image is actually more crucial for services than for physical products. Identity and image can impart tangibility and help customers get a "mental fix" on an otherwise undifferentiated service, transforming it into a virtual product (Onkvisit and Shaw 1989). An image that successfully draws upon the needs and values of consumers can provide confidence, security, and a higher guarantee of consistent quality. Also, since services consist largely of the interface between the provider and the customer, a pleasant service atmosphere is of paramount importance.

When thinking about how BRT elements contribute to brand identity, it is helpful to recognize that there are ways that the style or perceived design are improved and ways that the fundamental service qualities can be improved. To lend a tangible quality to BRT service, the most noticeable physical elements should be leveraged as much as possible. Distinctive logos, color combinations, and graphics should be consistently applied to vehicles, stations, running ways, and printed materials. Sleek, rail-inspired vehicles with spacious interior designs project a modern, upscale image, distinguishing BRT from older "shoebox"-style buses (Peak et al. 2005; Zimmerman and Levinson 2004). Attractive running ways and modern, comfortable vehicles and stations convey the idea that BRT service provides the style, amenities, and capacity of rail. Image also can be enhanced with design features that are distinct and highly visible. Design that complements the brand identity of a BRT system can strengthen the image of the service and reinforce the core marketing message aimed at passengers. Most BRT systems have stations with design cues to distinguish BRT routes from regular local bus service. Unique, eye-catching architecture and design elements also can be used to indicate where to gain access to the system.

In addition to physical design and aesthetics, identity and image also relate to aspects of service quality such as reliability and comfort. Exclusive right-of-way and signal priority, which are defining characteristics of BRT service, help ensure that service is more reliable. Advanced fare collection systems, multiple doors, automated guidance systems, and precision docking may reduce dwell times and enable levels of convenience in passenger boarding and alighting that approach rail (Zimmerman and Levinson 2004). These advanced technologies may also act as "authority symbols," communicating the professional legitimacy of the service provider and reducing the perception of risk (Cobb-Walgren and Mohr 1998). Furthermore, because consumer perceptions depend heavily upon interactions with service providers, customer contact personnel should be carefully chosen and trained to interact well with customers.

Effects of BRT Elements on Brand Identity

Several BRT elements affect brand identity.

Level of Running Way Priority

Just as the physical rail tracks of a rail transit line reinforce the idea that high quality rail service is present, running ways that have distinct identities support the idea that high quality BRT service is present. This strengthens the identity of the BRT system. The ability to impart and reinforce system identity becomes stronger with increasing levels of priority. Exclusive right-of-way also may reinforce the perception of rapid, reliable service.

Running Way—Marking

Similar to running way segregation, running way markings can also supplement brand identity. Examples of differentiation techniques include **pavement markings and signs** (e.g., frequent "bus only" markings on the pavement), particularly active signage (e.g., "BRT Only"), and **uniquely-colored running way pavement** (e.g., maroon in Europe, green in New Zealand, yellow in Nagoya and Sao Paulo). Running way markings advertise the BRT system by providing it with a distinct image and also make enforcement easier when there is no barrier separating the BRT-only running ways from general traffic.

Stations—Station Type

Perhaps no better opportunity exists to send tangible cues and create a unique identity and theme throughout a BRT system than station design. The unique identity of BRT stations should create a systemwide, unified theme that is easily recognizable to customers and emphasizes BRT's unique attributes of speed and reliability. This can be accomplished with distinct design cues that differentiate BRT from local bus service and unique, eye-catching architecture and design elements that advertise the service and indicate where to gain access to the system. Consumer perceptions of services also depend heavily on the service atmosphere. **Enhanced stops**, larger **designated stations**, and **intermodal terminals** advertise the BRT service and can enhance its image by providing an environment that is safe, attractive, comfortable, convenient, and accessible to disabled customers.

Vehicles—Vehicle Configuration

Vehicles may be the single most important element of user and non-user perceptions of a BRT system's quality. The styling and aesthetics of BRT vehicles and interior designs help distinguish BRT from local bus service, presenting BRT as a new concept or "mode." For this reason, BRT system identity is enhanced when BRT services are served by dedicated BRT vehicles. Vehicle configurations that provide enhanced body designs—**stylized standard and articulated vehicles and specialized BRT vehicles—**support positive impressions of BRT. Uniquely-styled vehicles advertise that the BRT system provides a distinct service and sends a tangible cue that indicates stopping locations and routes. Examples of advanced vehicle configurations include larger sizes for greater carrying capacity, aerodynamic designs, multiple sets of doors, covered rear wheel wells, comfortable seats, and roomy, open standing areas, all of which add to the vehicle's rail-like feel.

Vehicles—Aesthetic Enhancements

Vehicles with unique branding and livery (e.g., paint schemes, colors, and icons) can help achieve a distinct image, conveying important customer information such as routing and stations served, as well as alerting infrequent riders where they can board. A common and successful enhancement is the use of **specialized logos and livery**, especially when the visual scheme complements BRT stops, stations, terminals, signs, maps, and other sources of information, further solidifying the identity of the system as a whole.

Use of **large panoramic windows** and **enhanced lighting** can reinforce brand messages of being "open" and "safe." Low-floor buses generally have larger windows. The large windows and high ceilings provide the customer with a feeling of spaciousness, which contributes to the comfort of passengers.

Vehicles—Propulsion System

Clean propulsion systems and fuels have positive effects on image and branding of the service. BRT vehicles that are designed to run smoothly and reduce noise levels and air emissions may help do away with stereotypes of the noisy, polluting buses. There is a trend toward innovations in environmentally-clean vehicles such as hybrid-electric vehicles and vehicles fueled with compressed natural gas (CNG) and ultra low sulfur diesel.

Fare Collection—Fare Collection Process
Fare pre-payment contributes to BRT's resemblance to rail service. Complete pre-payment with **off-vehicle fare payment**, either through **barrier-enforced** or **barrier-free proof-of-payment**, allows for the optimization of bus operations, thus improving the system's image and brand identity. Fare inspectors associated with barrier free proof-of-payment systems also provide another customer service interface. Because inspectors represent the system, there is an important balance between enforcement vigilance and an understanding customer service approach.
Fare Collection—Fare Media and Payment Options
Alternative fare media relate BRT systems to high technology and user-friendliness. **Smart cards** provide quick transactions that enhance the image of BRT service as a high technology and high efficiency system. Although involving significant investments, they provide substantial benefits, including the possibility of auxiliary services (e.g., vending machines, parking, tolls, etc.) and the creation of seamless regional transit services with integrated fare collection. **Magnetic stripe cards** have many of the same benefits as smart cards, although with slightly longer transaction times.
ITS - Transit Vehicle Prioritization, Intelligent Vehicle Systems, Passenger Information Systems
Advanced technologies communicate the professional legitimacy of the BRT service provider and increase customer perceptions of overall safety and security. The inclusion of ITS elements also can strengthen the association of the BRT brand with innovation and cutting-edge technology. **Transit signal priority** can be marketed as just one improvement that distinguishes BRT service from regular bus service. **Precision docking** can help brand BRT as a "smart" service with the ability to precisely stop at the same location each and every time. **Real-time traveler information** options suggest that the system is technologically advanced enough to provide useful and timely information to customers. More advanced systems, such as **collision warning** and **automated lane guidance**, enhance safety and provide a smoother ride.

Worldwide, the interest in modern-looking, specialized BRT vehicles has led to development of several models, including Irisbus' Civis in France, the Bombardier "GLT" in Belgium and France, the Berkhoff-Jonkhere Phileas in the Netherlands and the Wright Bus in Northern Ireland. Manufacturers in North America (including Gillig, NABI, New Flyer and Orion) also are developing new models that incorporate aesthetics into their designs.

Of course, BRT elements alone do not define the total contribution to BRT brand identity. The successful deployment of personnel and employment of business practices also contribute to a BRT system's brand identity. Because consumers are likely to assess the quality of a service based on interactions with the service provider, customer service personnel should be carefully chosen and trained. Firms may also use employee appearance to achieve specific imaging or branding goals. For instance, uniformed operators trained in the use of high-tech equipment convey the provider's professional legitimacy (Cobb-Walgren and Mohr 1998), while security officials provide a greater sense of safety and security and reduce the perception of risk.

Performance of Existing Systems

The following descriptions of branding approaches to BRT projects show the range of possibilities when composing a brand and assembling BRT elements to reflect that brand identity.

Research Summary

The need to address the image of BRT is documented by differences in consumer response between rail and conventional bus service. Rail service tends to attract more riders than bus service even if all functional service attributes are equal (speed, frequency, span, etc). To reflect this stronger consumer response to certain modes, travel demand forecasts incorporate the use of mode constants to capture the effects of qualitative service attributes in mode choice modeling. These constants are a measure of the degree to which, all else being equal, one mode is more or less attractive than another. Mode choice models assume that mode constants will capture qualitative service attributes that are not explained by the easily quantifiable variables (such as travel cost and time) used in most models. These intangible service attributes (often called mode specific factors, or MSFs) present a challenge for empirical research because they are difficult to quantify and measure consistently across transit systems. Intangible service attributes often include qualities such as comfort, safety, security, and ride quality.

The disparity in consumer response between rail and on-street bus service appears to be due, in part, to qualitative attributes relating to image and perception. Design elements of rail provide distinct image benefits that might explain the apparent popularity of light rail over bus (Brown et al. 2003). For instance, riders like clear, understandable routes and vehicles and stations that are designed to be attractive and comfortable. Rail travel often is perceived as faster, more comfortable, quieter, safer, more reliable, and less polluting than on-street bus (Ben-Akiva and Morikawa 2002; U.S. General Accounting Office 2001). Although rail has a clear advantage over conventional bus service in terms of ridership potential, there is limited information on how rail compares to BRT in this regard. However, the few studies that do exist suggest that if functional service characteristics and infrastructure are comparable, BRT should attract riders at a level similar to light rail. Ben-Akiva and Morikawa (2002) argue that "a high-quality express bus service with exclusive right-of-way may be equally attractive to Metro service." Clearly, this has profound implications for high-quality BRT, which is capable of operating much like a light rail system.

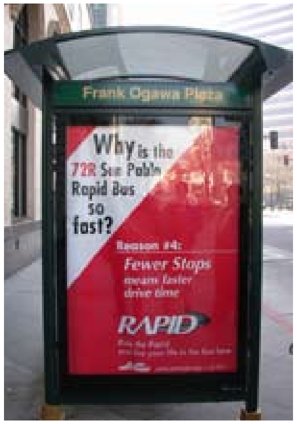
If there are differences in ridership attraction between rail and BRT, they appear to lie in the intangible attributes that relate to image and perception. Henke (2007) draws on the findings of several different studies to conclude that up to one-third of median ridership gain observed across six new BRT systems could not be explained by quantifiable service improvements and that most of this unexplained aspect was due to branding and image. Indeed, in addition to emulating the functional aspects of rail, BRT shows great promise for replicating many of the image attributes that attract choice riders to rail.

However, there is limited research knowledge regarding the impact and cost-effectiveness of BRT in terms of image improvement. Current research at the National Bus Rapid Transit Institute (NBRTI) aims to quantify the impact of different BRT system design elements on overall image and assess the extent of the relationship between positive image and ridership gain. It is hoped that this will allow agencies considering BRT to determine how best to convey a quality image in the most cost-effective manner. To discern the role of image in mode-choice decisions, the research will assess differences in perceptions between BRT and other modes, particularly rail transit and the private automobile. Because the success of BRT in reducing traffic congestion depends heavily on attracting choice riders, the NBRTI study intends to examine the image perceptions of this group to determine the extent to which image plays a role in their mode-choice decisions. One study found that when dedicated bus lanes were provided, they were perceived as offering travel time savings over the automobile (Cain and Sibley-Perone 2005).

System Performance Profiles

San Pablo Rapid, Alameda, and Contra Costa Counties (California)

The branding of the San Pablo Rapid features special designs for the vehicles and stations. The sleek, state-of-the art, 100 percent low-floor Van Hool vehicles dedicated to the San Pablo Rapid feature the eye-catching red and white "Rapid" logo and prominent graphics on all sides of the vehicle. The distinctive "Rapid" logo and graphics also are featured prominently at San Pablo Rapid stations.



Silver Line, Boston

The Silver Line bus service is branded as a new line of the MBTA's rapid transit system. The other color-coded lines on the system are heavy rail and light rail. The Silver Line is the first MBTA bus line that has been branded as rapid transit. As such, it is included in the rapid transit map and route schedule. Like the rapid transit lines, but unlike all other MBTA bus lines, the Silver Line has named stops and strip maps at stops and onboard vehicles. Also unlike most bus routes, a subway pass is valid on the Silver Line, and a free transfer to other rapid transit lines is available for those paying cash. The silver color is used on the vehicles (which have a special Silver Line livery), stations, signs, logo, and marketing materials.

MAX, Kansas City

To distinguish MAX service from local buses, vehicles have a unique shape and paint scheme that prominently displays the MAX logo. Similar to light rail, MAX has stations with clearly identifiable names (e.g., Midtown or Crown Center) and real-time transit information. All MAX stations are well-lit and feature a specially-designed passenger shelter and a distinctive 17-foot high information marker with the MAX logo at the top. The design of the MAX map adds further to the resemblance of light rail by using simple route geometry and stop labels.

MAX, Las Vegas

For the Las Vegas MAX BRT system, planners at the Regional Transportation Commission (RTC) of Southern Nevada developed a branding specification that highlighted all aspects of an alternative transit experience. The MAX system combined a sleek, state-of-the art vehicle, uniquely designed passenger stations, and an exclusive marketing campaign to introduce the service and educate citizens and visitors alike regarding BRT in the Las Vegas metropolitan area. The MAX vehicle features a striking, high-gloss blue, white, and gold exterior that prominently displays the MAX logo. To further brand the MAX system, the same prominent color scheme and logo are integrated into the identification of stations, signage, ticket vending machines (TVMs), and the overall paint scheme of the facilities. The marketing campaign employed free “Try MAX on Us” passes, MAX promotional labels on give-away bottled water, and colorful information packets. Additionally, outreach events were held throughout the community to teach riders how to use the TVMs.

Metro Rapid, Los Angeles

In Los Angeles, the introduction of a unique branding specification for Metro Rapid service has been critical in getting the riding public to associate Metro Rapid with high-frequency, limited-stop service. In the case of Metro Rapid, the success of the program was very much predicated on Metro’s service formula, which operates 4-5 minute peak hour headways on its Wilshire and Ventura lines. The riding public immediately associated Metro Rapid’s distinct red buses and distinct stations with high-frequency, headway-based service, and this branding strategy eased the challenge of expanding the market niche for high-frequency regional express service. Eventually, the success of this branding approach prompted the Los Angeles County Metropolitan Transportation Authority to change how it branded its local service, imitating a similar design scheme for vehicles but using a different distinct color to suggest tiers of service.

South Miami-Dade Busway

The South Miami-Dade Busway is Miami-Dade Transit's state-of-the-art bus rapid transit system. Branding of the service is centered around the system's 20-mile exclusive running way, which extends from the southern terminus of Miami MetroRail - Dadeland South Station. The at-grade, dedicated busway runs adjacent to Rt. 1, a high-growth corridor. The physical segregation of the busway enables the riding public to immediately identify the exclusive busway as a faster way to travel using transit. A total of 56 uniquely-designed and painted shelters serve the 28 stops along the busway. Extensive landscaping between the stations complements the beauty of neighboring communities and adds to the system's identity. Both full-size buses and minibuses operate on the busway and in adjacent neighborhoods, entering the exclusive lanes at major intersections. This fleet is not designated in any special way (e.g., through a different livery or logo).

LYMMO, Orlando

The LYMMO is a BRT route that operates on a continuous loop through downtown Orlando using gray running way pavers to indicate that the lanes are for LYMMO vehicles only. The LYMMO uses smaller, low-floor vehicles with colorful public-art exteriors to enhance the customer's experience and to give the system a unique identity. The LYMMO has 11 enhanced stations and 8 stops. The stations feature shelters that are unique to the LYMMO system. In addition to these branded aspects, the LYMMO also has a unique logo on vehicles, stations, and stops. LYMMO's unique branding and fare-free service have been important to its success as a high-frequency, fast, reliable, and premium transit service.

Orange Line, Los Angeles

The Orange Line, one of the first BRT lines with the comprehensive set of features associated with BRT systems in the U.S., began operating in October 2005. It features a 14-mile dedicated busway, high-capacity articulated buses, rail-inspired stations, level boarding, off-board fare payment, and headway-based schedules. To give the Orange Line a premium service image, the Los Angeles County Metropolitan Transportation Authority (Metro) has branded the route similar to how it brands its rail lines. It is the only bus line that has been given a color-coded name designation, the route is included on the rail system map, and the vehicles are painted in the same silver and gray color pattern as Metro rail vehicles. The 60-ft articulated "Metro Liners" are powered by compressed natural gas and feature aerodynamic styling, panoramic windows, low floors, wide aisles and doors, and on-board video monitors. All Orange Line stations have the same basic design and construction, ensuring a consistent, recognizable brand identity with integrated art elements, developed in a similar fashion as the art in the rail stations. Each station offers various amenities such as bicycle racks and lockers, covered seating, telephones, lighting, and security cameras. The Orange Line has an interactive website that highlights its similarity to rail and explains how to use the service.

EmX Green Line, Eugene

In January 2007, Eugene, Oregon joined Los Angeles as one of the first U.S. cities to launch a full-service BRT system. The four-mile EmX Green Line uses dedicated busways, exclusive bus lanes, transit signal priority, high-capacity vehicles with near-level boarding, widely-spaced stations, off-board fare collection, and short headways. A "green" image is a central theme of the branding strategy of the EmX (short for "Emerald Express"). The Green Line is the first operational route in what is planned to be a comprehensive system of BRT corridors. The routes will all be given color names instead of conventional bus route numbers. Approximately two-thirds of the service operates in exclusive lanes, which are constructed in concrete to distinguish them from general purpose lanes. Stations have raised platforms, display a consistent shelter design, provide real-time passenger information, and are located predominately in the median of the street to emphasize the rail-like nature of the service. EmX service is provided by modern, 60-ft articulated vehicles that have a sleek silhouette and multiple doors on both sides. In keeping with the "green" theme, the buses are hybrid-electric and are painted green and silver with the EmX logo.

BRT Elements by System and Brand Identity

Exhibit 3-14 presents a summary of BRT elements that support a differentiated brand identity for BRT systems in 36 cities around the world. The most common technique to give separate brand identity is the use of a different look for vehicles. In the U.S., this is the most popular branding technique, with roughly two-thirds of the U.S. BRT cities operating stylized vehicles and about 75 percent using a distinct livery for the BRT vehicles. Systems are also more likely to use articulated vehicles; while this may be done primarily to achieve capacity and headway targets, it does also support branding efforts, since most conventional fleets are served by 40-ft buses. Articulated vehicles also present a more "rail-like" appearance. It should be noted that there is a general trend in U.S. transit toward more "stylized" buses and, in some of the cities in Exhibit 3-14, the vehicle styling used for the BRT buses also is being adopted throughout the fleet. However, a distinct livery continues to be used to allow customers to distinguish the BRT vehicles from the regular fleet.

The three Canadian cities listed use varying strategies. Ottawa operates its standard fleet vehicles on the Transitway. By contrast, special vehicles are central to the York Region Transit's branding scheme for the VIVA. The agency purchased a separate fleet of stylized articulated vehicles for the VIVA, with a spacious interior configuration and distinct blue-and-white livery. Vehicles are also a strong branding component for the three Latin American systems.

Like the U.S., most, but not all, European systems use distinctly stylized and marked vehicles for their BRT systems. European cities are also the most likely to use some type of vehicle guidance mechanism, which can support a high-quality service image for BRT by allowing level boarding. The Australian systems often use conventional buses with a standard livery or a very minor distinguishing livery element. It should be noted that, in both Europe and Australia, conventional fleet buses already have many of the features associated with "modern styling" in the U.S., such as large, single-pane windshields, large side windows, and curving lines instead of boxy corners.

A few systems rely on a dedicated running way rather than vehicle attributes to brand the service. The Ottawa Transitway, the Pittsburgh busways, Brisbane's busways, and Adelaide's North East Busway all use regular fleet vehicles for busway operations. Overall, however running way location and running way priority are used less frequently, however, as a key branding element. Decisions about running way priority appear to be based primarily on considerations such as availability of right-of-way and capacity goals.

Stations also play an important role in branding for most of the systems summarized in Exhibit 3-14. Most systems offer enhanced shelters, at a minimum, with many using full station designs more often associated with rail systems. Decisions about station types are dependent on the running way location, which impacts the available space for the BRT stations and may limit the ability to implement stations with a substantial physical presence. Nevertheless, most systems strive to differentiate their BRT stops from conventional bus stops with greater levels of sheltering; seating, lighting and other passenger amenities; and a distinct design scheme often tied into the look of the buses. A few systems have invested in very substantial station structures—often at transfer points or service termini - that play an important role in the branding by raising the profile of the entire service. For example, the dramatic architecture of the underground Courthouse Station on Boston's Silver Line Waterfront BRT service led the *Boston Globe* to call it "one of the remarkable new spaces" in the city. Brisbane, Bogotá, Guayaquil, and Pereira also each feature some architecturally-noteworthy stations. (The section on "Contextual Design" has more discussion on the importance of stations to image of a BRT system.)

Latin America is the only region that consistently uses barrier-enforced fare collection as a strong branding element. The U.S., Australian, and Chinese systems still rely more on vehicle-based payment systems, while European systems frequently employ on-board payment in combination with proof-of-payment fare collection.

The primary ITS element used to support branding is passenger information. Most BRT systems have implemented passenger information systems at stations and on vehicles, or pre-trip planning via the web. Almost all the cities in Latin America, Europe, and Australia provide real-time passenger information at stations, while about half of the U.S. and Canadian systems do.

Exhibit 3-14: BRT Elements by System and Brand Identity

City, State / Province / Country	Albuquerque	Boston Silver Line	
BRT Line / System	Rapid Ride	Washington Street	Waterfront SL1 – Airport
Running Way (miles)			
On Street Mixed Lanes	13.1	0.2	3.5
On Street Exclusive Bus Lanes	0.7	2.2	
Off Street Mixed Lanes		0.0	
Off Street Reserved Lanes		0.0	
At-Grade Transitway		0.0	
Grade-Separated Transitway		-	1.0
Queue Jumpers			
Marking	Signage	Signage and Striping	
Station			
Type	Enhanced Shelter	No Shelter, Basic Shelter, Enhanced Shelter & Transit Center	No Shelter, Underground Station & Transit Center
Vehicles			
Configuration	Articulated	Stylized Articulated	Articulated
Description of Livery / Image	Red & White Paint, Rapid Ride Logo	Special livery	Special livery
Interior Features	Molded plastic with fabric inserts	Standard seats in 2+2 configuration	luggage racks for airport line
Propulsion System and Fuel	Hybrid-Electric, ULSD	ICE CNG	Dual-Mode diesel & electric, ULSD
Fare Collection			
Fare Collection Process	Pay on-board	Pay On-Board	Barrier at 3 underground stops; pay on board elsewhere
Fare Media and Payment Options	Cash & Paper only	Cash / Paper Transfers / Magnetic Stripe / Smart Cards	cash, paper ticket, smart card
ITS			
Transit Vehicle Prioritization	TSP	TSP - Green Extension, Red Truncation	No
Intelligent Vehicle Systems	None	None	None
Passenger Information	At Station / On Vehicle LED Nextbus signs	VMS at Stations and in-vehicle	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements
Identity and Image Performance			All 3 routes
Survey of Customer Perceptions		Yes	
Survey of General Customer Satisfaction exists? (yes/no)	Yes, High	A 2003 survey of passengers found that 90% of Silver Line Washington Street riders rate the service as "good to excellent."	In a 2006 passenger survey, 60% rated station features as good or excellent; 53% rated shelter amenities good or excellent; 70% rated driver courtesy good or excellent; 87% rated vehicle cleanliness good or excellent

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Boston Silver Line	Chicago	
BRT Line / System	Waterfront SL2 - BMIP	Western Avenue Express	Irving Park Express
Running Way (miles)			
On Street Mixed Lanes	1.2	18.3	9.0
On Street Exclusive Bus Lanes			
Off Street Mixed Lanes			
Off Street Reserved Lanes			
At-Grade Transitway			
Grade-Separated Transitway	1.0		
Queue Jumpers			
Marking			
Station			
Type	No Shelter, Underground Station & Transit Center	No Shelter	No Shelter
Vehicles			
Configuration	Articulated		
Description of Livery / Image	Special livery	Distinct electronic destination signs	Distinct electronic destination signs
Interior Features			
Propulsion System and Fuel	Dual-Mode diesel & electric, ULSD		
Fare Collection			
Fare Collection Process	Barrier at 3 underground stops; pay on board elsewhere	On Board	On Board
Fare Media and Payment Options	cash, paper ticket, smart card	Cash & Paper	Cash & Paper
ITS			
Transit Vehicle Prioritization	No		
Intelligent Vehicle Systems	none		
Passenger Information	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements		
Identity and Image Performance	All 3 routes		
Survey of Customer Perceptions			
Survey of General Customer Satisfaction exists? (yes/no)	In a 2006 passenger survey, 60% rated station features as good or excellent; 53% rated shelter amenities good or excellent; 70% rated driver courtesy good or excellent; 87% rated vehicle cleanliness good or excellent		

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Chicago	Cleveland	Eugene	Honolulu	
BRT Line / System	Garfield Express	HealthLine	EmX	City Express: A	City Express: B
Running Way (miles)					
On Street Mixed Lanes	9.4	2.7	1.4	19.0	8.0
On Street Exclusive Bus Lanes		4.4	2.6		
Off Street Mixed Lanes					
Off Street Reserved Lanes					
At-Grade Transitway					
Grade-Separated Transitway					
Queue Jumpers			Queue jump		
Marking		Signage	Raised delineators; concrete pavement, markings		
Station					
Type	No Shelter	Enhanced Shelter	Enhanced Shelter, Station Building	Basic Shelter	Basic Shelter
Vehicles					
Configuration		Stylized articulated	Stylized articulated	Articulated	Standard
Description of Livery / Image	Distinct electronic destination signs	Specialized Livery, Large Windows	Specialized Livery, Large Windows	Standard livery	Standard livery
Interior Features		Wide Aisles and Doors	Wide Aisles and Doors		
Propulsion System and Fuel		Hybrid diesel	Hybrid diesel	Diesel / Hybrid-Electric	Diesel
Fare Collection					
Fare Collection Process	On Board	Off Board, Proof of Payment	None—to be off board	Pay On-Board	Pay On-Board
Fare Media and Payment Options	Cash & Paper		N/A	Cash & Paper	Cash & Paper
ITS					
Transit Vehicle Prioritization		TSP	TSP		
Intelligent Vehicle Systems		mechanical guidance	Visual guidance		
Passenger Information		Real time passenger info	Vehicle, Web	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations
Identity and Image Performance					
Survey of Customer Perceptions					
Survey of General Customer Satisfaction exists? (yes/no)			A 2007 rider satisfaction survey yielded an average rating of 7.4 on a 10-point scale.	Yes	Yes

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Honolulu	Kansas City	Las Vegas	Los Angeles
BRT Line / System	Country Express: C	MAX - Main St	MAX	Orange Line
Running Way (miles)				
On Street Mixed Lanes	18.0	6.0	3.0	1.0
On Street Exclusive Bus Lanes		along certain segments, for certain times of day	4.5	-
Off Street Mixed Lanes	3.5		-	0.0
Off Street Reserved Lanes	17.5		-	0.0
At-Grade Transitway			-	13.5
Grade-Separated Transitway			-	
Queue Jumpers			1 queue jumper	
Marking	Zipper Lane Concrete Barrier	Bus Only Markings	Signage, Striping	At-Grade Busway, Signage at Intersections
Station				
Type	Basic Shelter	Enhanced Shelter	Basic and Enhanced Shelter	Enhanced Shelter
Vehicles				
Configuration	Articulated	Stylized Standard	Stylized Articulated	Stylized Articulated
Description of Livery / Image	Standard livery	MAX logo, unique livery and image, large continuous windows, sleek look	Sleek, modern lines with large windows,	Silver metallic two-tone paint scheme & Metro Orange Line name branding, large windows
Interior Features		Modern looking interior, increased aisle width, increase hip-to-knee room, wider doors, wider windows	modern auto like interior, finished window glazing	USSC Aries cloth seats
Propulsion System and Fuel	Diesel / Hybrid-Electric	ULSD	Diesel Electric Hybrid	ICE CNG
Fare Collection				
Fare Collection Process	Pay On-Board	Pay On-board	Proof-of-Payment	Proof-of-Payment
Fare Media and Payment Options	Cash & Paper	Cash & Magnetic Stripe	Magnetic Stripe	Tickets from TVM and standard paper passes
ITS				
Transit Vehicle Prioritization		TSP	TSP	
Intelligent Vehicle Systems			Optical Docking (not used)	None
Passenger Information	Traveler Information planned on vehicles, at several stations	Real-time at all stations, Trip Planning	Station, Telephone, Internet, On-Vehicle Electronic Displays	Nextbus VMS
Identity and Image Performance				
Survey of Customer Perceptions		yes	Yes	Y, very good
Survey of General Customer Satisfaction exists? (yes/no)	Yes	A 2005 on-board survey found that Max rated excellent on all 20 factors, that service quality was "High" and that riders would definitely recommend MAX.	A survey in February 2005 showed that 97% of riders rated their experience riding MAX as "good" or "excellent."	A 2006 rider survey found that 95% of riders like the Orange Line Metroliner vehicle and 91% like the pre-paid boarding system.

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Los Angeles	Miami	Oakland	Orlando
BRT Line / System	Metro Rapid (All Routes)	Busway	San Pablo Ave Rapid	LYMMO
Running Way (miles)				
On Street Mixed Lanes	229.5		14.0	
On Street Exclusive Bus Lanes	-			-
Off Street Mixed Lanes	0.0			
Off Street Reserved Lanes	0.0			-
At-Grade Transitway	0.0	20.0		3.0
Grade-Separated Transitway	-			
Queue Jumpers	Queue Jumpers		Queue jumpers	
Marking		At-Grade Busway		Busway Barrier, Gray Pavers
Station				
Type	No Shelter, Enhanced Shelter, Transit Center	Enhanced Shelter	Basic Shelter	Enhanced Shelter
Vehicles				
Configuration	Stylized Standard and Articulated	Standard, Articulated, Minis	Stylized standard	Stylized standard
Description of Livery / Image	Red/Silver two-tone paint scheme & Metro Rapid name branding	Standard Transit	Specialized Livery, Logos, Branding	Specialized Livery, Wide Doors
Interior Features				
Propulsion System and Fuel	ICE CNG	Hybrid, CNG, Diesel	Ultra-low-sulfur diesel	ICE CNG
Fare Collection				
Fare Collection Process	Pay On-board	Pay on Board	Pay On-Board	Free
Fare Media and Payment Options	Cash and Paper Passes	Cash, paper swipe card		Free
ITS				
Transit Vehicle Prioritization	TSP	No	TSP	TSP
Intelligent Vehicle Systems	None			Collision warning, lane assist, precision docking
Passenger Information	Nextbus VMS at stations, Telephone, Internet	Traveler information at stations and on vehicle	Real-time arrival at stations; traveler info on vehicle & via PDA	Traveler Information at stations and on vehicle; web-based
Identity and Image Performance		All 2004		
Survey of Customer Perceptions	Y, very good	65% see busway as attractive		93% view favorably
Survey of General Customer Satisfaction exists? (yes/no)	Customers give Metro Rapid a rating of 3.76 out of 5.00, compared to 3.15 for the former limited bus service	Average Satisfaction with Busway is 3.75 out of 5 compared to 3.61 for all MDT services.	83% of riders rate Rapid Bus as Good or Excellent compared to 72% who rated the system similarly in a survey 2 years prior.	Mean satisfaction: 4.41 out of 5.0; 52.5% of passengers have improved their opinions of public transit.

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Phoenix			
BRT Line / System	RAPID - I-10 East	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17
Running Way (miles)				
On Street Mixed Lanes	6.5	4.8	12.3	8.0
On Street Exclusive Bus Lanes				
Off Street Mixed Lanes				
Off Street Reserved Lanes	14.0	8.0	10.3	11.5
At-Grade Transitway	-	-	-	-
Grade-Separated Transitway				
Queue Jumpers				
Marking	Signage	Signage	Signage	Signage
Station				
Type	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter
Vehicles				
Configuration	Specialized composite bus	Specialized composite bus	Specialized composite bus	Specialized composite bus
Description of Livery / Image	Distinct styling & livery	Distinct styling & livery	Distinct styling & livery	Distinct styling & livery
Interior Features	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats
Propulsion System and Fuel	LNG	LNG	LNG	LNG
Fare Collection				
Fare Collection Process	Pay On-Board	Pay On-Board	Pay On-Board	Pay On-Board
Fare Media and Payment Options	Cash, Magnetic	Cash, Magnetic	Cash, Magnetic	Cash, Magnetic
ITS				
Transit Vehicle Prioritization	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection
Intelligent Vehicle Systems	Collision Warning	Collision Warning	Collision Warning	Collision Warning
Passenger Information	Real-time arrival at stations; on-vehicle announcements;, PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements;, PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements;, PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements;, PDA and web-based info.
Identity and Image Performance				
Survey of Customer Perceptions				
Survey of General Customer Satisfaction exists? (yes/no)				

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Pittsburgh			Sacramento
BRT Line / System	East Busway	South Busway	West Busway	EBus - Stockton
Running Way (miles)				
On Street Mixed Lanes				8.0
On Street Exclusive Bus Lanes				0.0
Off Street Mixed Lanes	0.4	-	0.4	0.0
Off Street Reserved Lanes	-	-	-	0.0
At-Grade Transitway			4.6	0.0
Grade-Separated Transitway	8.7	4.3		None
Queue Jumpers				1 queue jumper
Marking	Grade Separated	Grade Separated	Busway	None
Station				
Type	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	No Shelter, Basic Shelter, Transit Center
Vehicles				
Configuration	Standard & Articulated	Standard & Articulated	Standard & Articulated	Standard
Description of Livery / Image	Standard & Articulated	Standard & Articulated	Standard & Articulated	Standard Branded
Interior Features	Cushioned Seats	Cushioned Seats	Cushioned Seats	Standard
Propulsion System and Fuel	Standard Diesel with 5 CNG	Standard Diesel with 5 CNG	Standard Diesel with 5 CNG	ICE CNG
Fare Collection				
Fare Collection Process	Pay On-Board	Pay On-Board	Pay On-Board	Pay on-board
Fare Media and Payment Options	Cash and Paper Only	Cash and Paper Only	Cash and Paper Only	cash and passes
ITS				
Transit Vehicle Prioritization			Signal Priority (magnetic loop sensors)	TSP - Green Ext
Intelligent Vehicle Systems	Collision Warning	Collision Warning	Collision Warning	None
Passenger Information				On Vehicle
Identity and Image Performance				
Survey of Customer Perceptions				Yes
Survey of General Customer Satisfaction exists? (yes/no)			91% of riders surveyed indicated the West Busway was Very Important or Fairly Important in their decision to start using the bus.	Yes

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	San Jose	Halifax	Ottawa		
BRT Line / System	Rapid 522	MetroLink	95	96	97
Running Way (miles)					
On Street Mixed Lanes	25.0	12.1	2.1	2.1	2.1
On Street Exclusive Bus Lanes	0.0	0.5			
Off Street Mixed Lanes	0.0	10.6	3.2	13.1	5.2
Off Street Reserved Lanes	0.0	-	8.7	3.8	1.2
At-Grade Transitway	0.0	-	12.0	8.2	9.8
Grade-Separated Transitway	-	-			
Queue Jumpers	Queue Jumpers				
Marking	None	Signage	Signage, Pavement Color	Signage, Pavement Color	Signage, Pavement Color
Station					
Type	No Shelter, Basic Shelter and Enhanced Shelter; Transit Center	Basic Shelter, Station Enclosures	Station Enclosures and Buildings	Station Enclosures and Buildings	Station Enclosures and Buildings
Vehicles					
Configuration	Stylized Standard and Articulated	Stylized Standard	Articulated	Standard	Articulated
Description of Livery / Image	BRT-only full bus wraps	Blue, yellow, white patterned livery and unique branding	Maple leaf livery; similar to rest of fleet	Maple leaf livery; similar to rest of fleet	Maple leaf livery; similar to rest of fleet
Interior Features	Typical transit bus - front facing, upholstered seats	Cloth seats, reclining with arm / foot rests	Cloth seats	Cloth seats	Cloth seats
Propulsion System and Fuel	ICE LSD	ICE Biodiesel	ICE Low-sulfur diesel	ICE Low-sulfur diesel	ICE Low-sulfur diesel
Fare Collection					
Fare Collection Process	Pay On-board	Pay on-board	Proof-of-Payment	Proof-of-Payment	Proof-of-Payment
Fare Media and Payment Options	Cash and Paper Passes. Smart cards in development	cash / tickets / passes	Cash, Paper tickets, or passes	Cash, Paper tickets, or passes	Cash, Paper tickets, or passes
ITS					
Transit Vehicle Prioritization	TSP - Green Extension, Red Truncation	TSP	TSP	TSP	TSP
Intelligent Vehicle Systems	None	None	None	None	None
Passenger Information	Automated next stop announcements. Real-Time info in development. Automated trip planning through website	Real-time display, trip planning	Yes	Yes	Yes
Identity and Image Performance					
Survey of Customer Perceptions	No	Y, excellent			
Survey of General Customer Satisfaction exists? (yes/no)	Yes	Y, excellent			

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	York		Bogota	Guayaquil
BRT Line / System	VIVA Blue	VIVA Purple	Transmilenio	Metrovia
Running Way (miles)				
On Street Mixed Lanes	20.3	17.1	-	-
On Street Exclusive Bus Lanes			-	-
Off Street Mixed Lanes			-	-
Off Street Reserved Lanes			-	-
At-Grade Transitway			52.0	10.0
Grade-Separated Transitway				
Queue Jumpers	Bus-Only Lanes at some intersections	Bus-Only Lanes at some intersections	-	-
Marking	None	None	Busway, Signage	Busway, Signage
Station				
Type	Basic and Enhanced Shelter	Basic and Enhanced Shelter	Station	Station
Vehicles				
Configuration	Articulated	Standard	Stylized Articulated	Stylized Standard & Articulated
Description of Livery / Image	Metallic blue with Viva logo	Metallic blue with Viva logo	Red, branded articulated buses	Blue, branded articulated buses
Interior Features	Cloth seats in spacious arrangement and tables for workspace at some rear seats. WiFi being deployed. Large windows. Bright, large in-vehicle display screens	Cloth seats in spacious arrangement and tables for workspace at some rear seats. WiFi being deployed. Large windows. Bright, large in-vehicle display screens	molded plastic seats, front/rear and side facing	x
Propulsion System and Fuel	ICE Clean diesel	ICE Clean diesel	Diesel; CNG pilot project underway with 3 buses	x
Fare Collection				
Fare Collection Process	Proof-of-Payment	Proof-of-Payment	Barrier (Verify at station entrances / exits)	Barrier
Fare Media and Payment Options	Paper tickets or passes	Paper tickets or passes	Smart Cards	Cash, Smart Cards
ITS				
Transit Vehicle Prioritization	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction	x	x
Intelligent Vehicle Systems	None	None	none	None
Passenger Information	VMS at stops and on-board	VMS at stops and on-board	Nextbus displays at stations	Nextbus displays at stations
Identity and Image Performance				
Survey of Customer Perceptions	Excellent	Excellent	yes	
Survey of General Customer Satisfaction exists? (yes/no)	Excellent	Excellent	yes	

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Pereira	Amsterdam	Caen	Edinburgh
BRT Line / System	Megabus	Zuidtangent	Tram on Wheels	Fastlink
Running Way (miles)				
On Street Mixed Lanes	-	1.9		1.9
On Street Exclusive Bus Lanes	-	6.2	9.2	2.2
Off Street Mixed Lanes	-	2.5		-
Off Street Reserved Lanes	-	-		-
At-Grade Transitway	17.0	14.9	0.1	0.9
Grade-Separated Transitway				
Queue Jumpers	-	Queue Jumper		
Marking	Busway, Signage	Busway, Signage	Signage, concrete track with rail, landscaping	signage, color, segregation
Station				
Type	Station		Enhanced Shelters, Stations, Transit Centers	
Vehicles				
Configuration	Stylized Articulated	Articulated	Bi-Articulated	Standard single and double deck
Description of Livery / Image	Green, branded articulated buses	Zuidtangent logo, red braded buses	Blue & White- Twisto	Standard
Interior Features	molded plastic seats, front/rear and side facing		"bistro" style semi-circle seating at rear	
Propulsion System and Fuel	ICE diesel	Diesel	Dual Mode- Traction motor on-rail/ diesel engine off-rail	Diesel
Fare Collection				
Fare Collection Process	Barrier (Verify at station entrances)	Pay On-Board or Proof of Payment	Pay On-Board or Proof of Payment	Pay On-Board or Proof of Payment
Fare Media and Payment Options	Smart Cards	Paper (Strippenkart)	Smart Cards, Magnetic tickets	Cash Coin (Exact Change) or Smart Card
ITS				
Transit Vehicle Prioritization	x	RTSP	Signal Priority- Automatic	TSP
Intelligent Vehicle Systems	none	Only for Docking, Mechanical	Mechanical- Central Guidance Rail	Mechanical
Passenger Information	Nextbus displays at stations	Real-time stop information, timetabled	Real-time at Station/Stop, Online-journey planner and timetable	Real-time, at Station/Stop, SMS
Identity and Image Performance				
Survey of Customer Perceptions				yes
Survey of General Customer Satisfaction exists? (yes/no)				yes

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Eindhoven	Leeds	London	Rouen	Utrecht
BRT Line / System	Phileas - Western Corridor	Superbus	Crawley	TEOR	Busway
Running Way (miles)					
On Street Mixed Lanes	2.2	-	11.2	8.7	3.5
On Street Exclusive Bus Lanes		3.8	3.7	-	2.0
Off Street Mixed Lanes	-	-	-	-	-
Off Street Reserved Lanes	-	-	-	-	-
At-Grade Transitway	7.2	2.2	0.9	14.9	4.8
Grade-Separated Transitway					
Queue Jumpers			-		
Marking	Signage, concrete track, landscaping	Curb guidance, pavement markings, some pavement color	Signage, curb guidance	Color running way and slightly raised in downtown	Signage, pavement markings, pavement color
Station					
Type					
Vehicles					
Configuration	Articulated, Bi-Articulated	Standard	Standard	Articulated	Bi-Articulated
Description of Livery / Image	Phileas bus logo	Standard	Fastway logo, blue/grey branded buses, unique enhanced shelters	TEOR Logo (Transport Est-Ouest Rouennais)	Standard
Interior Features					
Propulsion System and Fuel	Hybrid (LPG/Electric)	Diesel	Diesel	Diesel	Diesel
Fare Collection					
Fare Collection Process	Proof-of-Payment, Pay On-Board machine, no driver payment	Pay On-Board	Pay On-Board	Off-board Fare Collection	Proof-of-Payment, Pay On-Board
Fare Media and Payment Options	Paper (Strippenkart)	Cash and Paper Only	Cash	Magnetic Strip	Paper (Strippenkart)
ITS					
Transit Vehicle Prioritization	TSP	Signal Priority in downtown areas		Signal Priority- Automatic and Manual	Signal Priority- Automatic
Intelligent Vehicle Systems	Electromagnetic docking (not in use)	Mechanical	Mechanical	Optical	-
Passenger Information	Real-time stop information, timetabled	Real-time, at Station/Stop, SMS	Time tabled, at Station/ Stop	Real-time stop information, timetabled	Real-time stop information, timetabled
Identity and Image Performance					
Survey of Customer Perceptions					
Survey of General Customer Satisfaction exists? (yes/no)					

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Adelaide	Brisbane		Sydney	
BRT Line / System	North East Busway	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea
Running Way (miles)					
On Street Mixed Lanes					
On Street Exclusive Bus Lanes				6.0	0.3
Off Street Mixed Lanes					
Off Street Reserved Lanes					
At-Grade Transitway				13.0	4.4
Grade-Separated Transitway		7.46	10.3	1.7	
Queue Jumpers					
Marking	Off-Street Busway, Signage	Off-Street Busway, Signage	Off-Street Busway, Signage	Signage, At-Grade Busway	Signage/Red Pavement Color; Busway
Station					
Type	Transit Centers	Stations, Transit Centers	Stations, Transit Centers	Basic and Enhanced Shelter; Stations	Stations, Transit Centers
Vehicles					
Configuration	Standard Articulated = 60 Standard Rigid = 80	Standard Rigid	Standard Rigid	Standard Rigid	Standard Rigid
Description of Livery / Image	Standard white and yellow - same as non busway corridors	Standard Brisbane White, Blue and Yellow	Standard Brisbane White, Blue and Yellow	Standard Sydney Bus Livery - Blue White and Yellow - with T-Way Logo	White Red Stripe
Interior Features	Luggage racks over wheel hubs				
Propulsion System and Fuel	Diesel	Mix of Diesel and CNG Gas Buses	Mix of Diesel and CNG Gas Buses	Euro 3 diesel	Diesel
Fare Collection					
Fare Collection Process	Pay on Board (80% pre pay multi-rider ticket)	Pay on Board	Pay on Board	Pay on Board	Pay on Board
Fare Media and Payment Options	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe
ITS					
Transit Vehicle Prioritization	Passive Priority (No active)	-	-	Signal Pre-emption including green extension and early green	-
Intelligent Vehicle Systems	Mechanical Guide Rollers on Front Axle	None	None	None	None
Passenger Information	City Web Site has Trip Planning	Real Time Info at Stations	Real Time Info at Stations	Real Time Info at Stations	Real Time Info at Terminus Stations Only
Identity and Image Performance					
Survey of Customer Perceptions	yes	yes	yes	yes	
Survey of General Customer Satisfaction exists? (yes/no)	yes	yes	yes	yes	

Exhibit 3-14: BRT Elements by System and Brand Identity (cont'd.)

City, State / Province / Country	Sydney	Beijing	Hangzhou	Kunming
BRT Line / System	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Line B1	Busway network
Running Way (miles)				
On Street Mixed Lanes				
On Street Exclusive Bus Lanes	1.9		6.2	
Off Street Mixed Lanes		2.2		
Off Street Reserved Lanes				24.9
At-Grade Transitway	8.7	8.1		
Grade-Separated Transitway				
Queue Jumpers				
Marking	Signage/Red Pavement Color; Busway	Busway	Striping	Striping
Station				
Type	Basic and Enhanced Shelters, Transit Centers	Stations		
Vehicles				
Configuration	Standard Rigid	Articulated	Articulated	Standard
Description of Livery / Image	Yellow	Specialized BRT vehicles	Specialized red BRT vehicles	
Interior Features				
Propulsion System and Fuel	Diesel			Diesel
Fare Collection				
Fare Collection Process	Pay on Board	Pay attendants at station	Pay at station	Pay On-Board
Fare Media and Payment Options	Cash & Paper Magnetic Stripe	Cash / Smart Cards	Cash / Smart Cards	Cash / IC Cards
ITS				
Transit Vehicle Prioritization	-	TSP	TSP	
Intelligent Vehicle Systems	None	None	None	None
Passenger Information	Real Time Info at Terminus Stations Only	Real-Time at stations and on vehicles	Real-Time at stations and on vehicles	Currently being implemented
Identity and Image Performance				
Survey of Customer Perceptions				Yes
Survey of General Customer Satisfaction exists? (yes/no)				Yes

Contextual Design

Description of Contextual Design

A well-designed BRT project complements the scale and character of the surrounding area and can shape a community in ways that go beyond transportation benefits alone. Quality of life is enhanced when systems are designed to harmonize with their context and create a sense of place for the communities they serve. Designing BRT as an integrated part of the community can channel a wide spectrum of benefits relating to the environment, the economy, aesthetics, public health and safety, and civic participation.

For instance, a well-designed BRT project can serve as a focal point that draws the community together. Unfortunately, public space often is neglected in the design of transportation projects, where the focus is on moving people around (Forsyth et al. 2007). Good public spaces provide a hospitable setting for people to stop and read, eat lunch, or meet with friends. To that end, introducing a BRT system into a community can be viewed as an exercise in urban design. BRT facilities can create a more welcoming, vibrant streetscape by incorporating amenities such as landscaping, sidewalks, lighting, street furniture, and recreational trails.

Accessibility and connectivity to the broader urban fabric should be emphasized as crucial elements of contextual design (Neckar 2007). BRT can make a significant contribution to community integration only when the system is accessible for all who wish to use it. Because transit facilities serve as a transition between different modes, they must be carefully tailored to balance the needs of pedestrians, bicyclists, transit riders, and motorists. Moreover, in addition to providing access for all, facilities must be designed to accommodate and protect the most vulnerable users (Forsyth et al. 2007). ADA requires adequate circulation space within a bus shelter, provision of sidewalks, bus stops that are connected to streets and sidewalks by an accessible path, and readable bus route and schedule information. Open accommodation to all users is, therefore, an important consideration when address the contextual design of the system.

Effects of BRT Elements on Contextual Design

The BRT elements that impact contextual design most strongly are discussed below.

Running Ways—Running Way Location, Level of Running Way Priority
On-street running ways, by their very nature, are integrated with commercial and residential uses along major arterial streets. They also have more direct pedestrian access between activity centers and the systems.
Off-street running ways are less integrated with the urban environment. One potential advantage of the separation from the street network is that potential effects of noise and vibration may be shielded from adjacent communities through a spatial distance buffer or physical barriers, thereby harmonizing with sensitive land uses. Landscaping associated with off-street running ways also enhances the design and image of the BRT system.
Designated running ways that are attractively designed can convey a sense of quality and permanence that potentially attracts developers and residents who desire high quality transit service. Running ways also affect the physical environment of the surrounding neighborhood. Running Way Types that shield potential effects of noise and vibration can harmonize best with sensitive land uses. Landscaping with native trees and plants can reinforce a sense of place and integrate the running way with the overall design concept of the surrounding neighborhood.
Running Way—Marking
Attractive running way differentiation techniques can advertise the BRT system and reinforce the image of high quality transit service. Specially-colored pavement or "Bus Only" signs and markings should attract attention to the service without being garish or intrusive. When designed properly, running way differentiation can strengthen the distinct identity of the system while blending with the scale and style of the streetscape and surrounding neighborhood.
Stations—Station Type
The level of attention devoted to the design and architecture of BRT stations and the degree to which stations integrate with the surrounding community impacts how potential customers will perceive the BRT system. This has a direct impact on BRT system ridership, as well as an indirect impact on nearby development and neighborhood revitalization. Station design also presents the opportunity to impart the system with unique local character and community ownership by incorporating elements such as native landscaping, historic preservation, and local artwork. Stations also should provide a full range of amenities such as passenger information, telephones, vending machines, lighting, and security provisions.
Stations—Station Access
It is important for the system to be accessible to the entire community. To that end, the design of stations and shelters should specify adequate internal circulation, connection to streets and sidewalks by an accessible path, provision of sidewalks, readable route and schedule information, and generous accommodations for bicyclists and people with disabilities.

Vehicles—Vehicle Configuration
Community integration can be significantly enhanced when vehicles are designed to be accessible to all members of the community. Accommodations such as storage space for bicycles and wheelchairs, level boarding, ramps, and next-stop voice and text announcements help send the message that the system belongs to everyone.
Vehicles—Aesthetic Enhancements
Vehicle styling can have a significant impact on the ability of the BRT system to fit within the context of the community. Styling that emphasizes various features such as large vehicles to simulate rail (Los Angeles Orange Line, Eugene EmX), sleek lines and attractive interiors (Las Vegas MAX), and colors to suggest a high-technology theme (Boston Silver Line) can enhance the ability of a BRT system to integrate with the community. In addition, uniquely-styled vehicles can act as a tourist attraction in their own right and become a distinct trademark of the community. Branding and paint schemes incorporating themes that are relevant to the area can add local flair and bring a sense of community pride to the system.
Vehicles—Propulsion System
As well as contributing to the image and brand identity of BRT service, propulsion systems and fuels can have clear positive effects on community integration. Furthermore, public health and quality of life in the community can be enhanced with innovative propulsion technologies that mitigate noise and air pollution.

Performance of Existing Systems

The benefits of contextual design are difficult to measure and quantify and even more difficult to cast in terms of monetary value. Therefore, it is inappropriate to use quantitative terms to evaluate the relative effectiveness of BRT investments in achieving contextual design.

Research Summary

There are numerous detailed case studies where transit facilities with significant levels of amenities, irrespective of mode, have had a strong positive impact on surrounding communities. In addition, BRT improvements that interface with adjacent land uses and provide capacity for future growth can catalyze new development and revitalization of existing neighborhoods and downtowns. Case studies documenting integral and contextual design approaches are presented in TCRP Report 22, "The Role of Transit in Creating Livable Metropolitan Communities." In places including Boston, Houston, Seattle, Miami, and Pittsburgh, BRT and other quality bus facilities have demonstrated the ability to generate positive development and redevelopment when other factors such as the development market and local land use policies are supportive.

System Performance Profiles

The following section presents system profiles of successful designs as well as a summary of system characteristics that have an effect on contextual design. System profiles are useful to illustrate good examples of attractive systems and successful integration of BRT systems with their surrounding communities.

LYMMO, Orlando

In Orlando, the LYMMO system provides superior service on a downtown circulator route. LYMMO uses a variety of BRT elements—dedicated lanes with specialized paving, advanced computer monitoring systems, real-time bus information at stations, specially-designed station shelters, and vehicles that are decorated in themes relevant to Orlando's tourism industry. Design of the stations and running way were developed in conjunction with the streetscape for downtown Orlando, providing an integrated look to the system. This combination of elements has highlighted the service and resulted in significant ridership gains by establishing a high-quality, free bus service in the downtown area. LYMMO was developed as a distinct brand with its own logo and vehicles. Free fares also are part of its appeal to the riders.

South East Busway, Brisbane

The South East Busway in Brisbane, Australia represents an achievement in system design. The design of the system, especially at stations, emphasizes transparency and openness through the use of generic design using clear glass and simple linear steel forms. This canopy and station architecture theme is carried into all stations. The openness and transparency of the design assure visibility, thereby reinforcing impressions of public safety. While the basic station

form is repeated at all stations, the configuration of station architecture is tailored to specific site contexts. For example, the design and landscaping of Griffith University Station includes plantings from the nearby Toohey Forest. The landscaping at the Buranda Station features palm trees and other subtropical plants native to the province. The consistency of station design enables first-time users and the public to gain familiarity with the stations. The simplicity of station design facilitates the movement of passengers and vehicles through the system. The design has won multiple accolades, including a nomination for the Australian Engineering Excellence Awards 2001 and an Award of Commendation in the 2001 Illuminating Engineering Society State Lighting Awards.

Metro Orange Line, Los Angeles

The Metro Orange Line began operating in October 2005 as one of the first "full-service" BRT systems in the U.S. The Orange Line features a 14-mile dedicated busway that runs along an inactive rail corridor, high-capacity articulated buses, rail-like stations, level boarding, off-board fare payment, and headway-based schedules.

The Orange Line is a fleet of 60-ft articulated "Metro Liners", powered by compressed natural gas. The buses have space for two bikes and two wheelchairs, and three extra-wide doors. On-board video monitors recently were installed for an added level of security. Each station offers bicycle racks and lockers, covered seating, ticket vending machines, telephones, lighting, spacious sidewalks, and security cameras. Six stations have lighted park-and-ride lots, supplying a total of 3,800 free parking spaces.

To create a unique sense of place, each station has been given the attention of a select California artist. The artwork maintains continuity of design while also giving each station a unique theme relevant to the history of the San Fernando Valley. Artworks include terrazzo paving at platforms, colorful porcelain steel art panels at each station entry, sculpted seating, and various landscaping designs. Sound walls and irrigated landscaping along the busway help the Orange Line to blend into the surrounding environment. As an added benefit to the community, the design of the Orange Line includes 14 miles of bikeway and 8 miles of pedestrian paths, complete with fencing and crosswalks to ensure safety.

Land use was a key consideration in selecting the Orange Line BRT running way and stations over simpler expressions of BRT. The long-term development plan for Los Angeles includes high-capacity transit at certain major activity centers to encourage transit oriented development. Large multi-unit developers already have expressed interest, and Metro is reviewing joint development contracts to construct over two million square feet of mixed-use development at several stations. These developments would combine park-and-ride, residential, and commercial facilities with ground floor retail and office space. Metro also has committed to a $3.6 million renovation project in a historic district near the North Hollywood station (Callaghan and Vincent 2007).

EmX, Eugene

The Emerald Express (EmX) BRT system, operated by Lane Transit District (LTD) in Eugene, Oregon, commenced service in January 2007 as one of the first full-featured BRT systems in the U.S. The EmX uses a variety of BRT elements, including dedicated lanes with specialized paving, signal priority, modern vehicles, level boarding, advanced computer monitoring systems, specially-designed stations with real-time information, and a unique brand identity. Since opening, the EmX Green Line has surpassed all ridership estimates, carrying more than 1.4 million boardings in its first year. BRT was chosen as the preferred transit strategy in Eugene, not only for its significant enhancements to transit service but also because it is appropriate in scale and cost for the surrounding community. The system was designed to have a consistent look that would complement the character of the community. Arborists, urban foresters, concrete specialists, traffic engineers, architects, and landscapers were consulted during every phase of the project. Community integration and accessibility were primary design goals from the outset of the project.

Station design, inspired by the concept of "masted sails," provides shelter and comfort to customers while also complementing the landscape. The open design allows maximum visibility to improve customer safety and reduce vandalism. LTD staff also worked closely with cycling groups and people with disabilities to design a system that would be accessible to everyone. A bicycle lane runs along the corridor of the Green Line, and vehicles have storage space for three bicycles. Median stations, audible crossing signals at intersections, ramps and railings, warning pavers, and level boarding create an easy-to-use system for people with disabilities. The 60-ft articulated vehicles feature doors on both sides, near-level boarding, space for two wheelchairs, and next-stop voice and text announcements.

Concern for the environment and appreciation of local culture and ecology are central to the hallmark "green" image of the EmX. A unique trait of the EmX is that each station showcases the metalwork of local artist Linn Cook, who uses aluminum forms of native plants to feature a different species at each station. The image of innovative, environmentally-friendly public transit is further embodied in EmX's clean, quiet hybrid electric vehicles. Grass in the center lane of the running way adds greenery while also helping to absorb noise. Native landscaping at stations and along the corridor benefit the natural ecosystem. LTD's commitment to the environment was recognized with a 2008 Sustainable Transport Honorable Mention from the Institute for Transportation and Development Policy. After less than one year in operation, the EmX is the only U.S. BRT project selected as an award winner for 2008.

BRT Elements by System and Contextual Design

Exhibit 3-15 presents a summary of BRT elements that support contextual design for BRT systems in 36 cities around the world. As with system branding, decisions about running way location and priority are likely to be made for reasons other than contextual design considerations, primarily to serve travel time, reliability, and capacity goals and as a function of available right-of-way. As a result, not surprisingly, there is a wide range of running way locations and priority levels to be found throughout the 36 cities summarized in Exhibit 3-15. As discussed above, there are two ways that running way location can have a direct impact on contextual design.

First, on-street running ways offer greater opportunities to create attractive public spaces, especially if the BRT operates through city streets. Some cities have taken advantage of their urban location by not only building a BRT running way but renovating or rebuilding the surrounding streetscape. For example, for its HealthLine BRT project, Cleveland RTA not only constructed the busway along Euclid Avenue but also funded a complete streetscape renovation including reconstruction of concrete sidewalks with brick inlay, new curbs, complete sewer and water system upgrades, and amenities such as new light fixtures, landscaping, and sidewalk benches. The Massachusetts Bay Transportation Authority undertook a similar renovation effort along Boston's Washington Street corridor when implementing the Silver Line (Callaghan and Vincent 2008). This level of investment in the surrounding area is not typical of most BRT systems, however.

The second type of impact that running way location has come from off-street running ways. This type of running way design allows any potential negative noise and vibration impacts to be isolated from surrounding neighborhoods. This is the case with the Los Angeles Orange Line, where the transit agency also implemented sound walls to protect nearby houses from vehicle noise. In Ottawa, about nine kilometers of the Transitway lie in an open cut and are fully grade-separated, with underpasses for crossing below the surrounding roadways. Other Transitway sections that are at-grade typically are not adjacent to residential areas and therefore do not require noise mitigation.

Off-street running way locations also permit agencies to implement attractive landscaping along the busway. Los Angeles and Miami are two cities that used landscaping around their dedicated off-street busways to create a more attractive surrounding environment.

Another running way feature that can impact contextual design is the choice of markings. Only a few systems have used colored pavement instead of the standard bus lane markings, which not only serves the purpose of differentiating the BRT right-of-way but also makes the busway more attractive. Most of the European cities in Exhibit 3-15 use colored pavement; in the U.S., the Eugene EmX and Los Angeles Orange Line have used concrete pavement, which is different from adjacent asphalt pavement. Eugene also employs a grass strip down the middle of its median running ways, which helps create a "green" look that complements the city's natural surroundings.

The most common means to articulate a unified design in BRT systems is the use of enhanced shelters or full stations. The majority of BRT systems around the world use enhanced stations at a minimum, creating a permanent visual representation of the BRT system in the community. Often these designs are articulated to a greater degree with more exclusive running way facilities, as they are with the Pittsburgh busways, Ottawa Transitway, Brisbane busways, Los Angeles Orange Line, and all three Latin American cities in Exhibit 3-15. Some cities have designed their stations to reflect or complement the surrounding aesthetic. For example, Brisbane chose an open architecture with clear glass to create a feeling of openness and connectivity to the surrounding environment.

While they may be smaller due to space concerns, on-street stations or shelters can enhance the surrounding streetscape, especially because they are located directly in the common public space. While the data summary show that most BRT systems use an enhanced shelter or station architecture, is difficult to determine how well these stations are integrated into the community. Many cities have worked closely with communities adjacent to the BRT running way to ensure that the station design is compatible with their surroundings. For example, the York Region's VIVA and the Cleveland HealthLine have multiple station designs based on the needs and input of the immediate neighborhood. For stations in Cleveland's Central Business District, the transit agency designed smaller stations with a more "historic" look to complement the historic downtown architecture and narrow cross streets; for the Midtown region, which has a wider streetscape and more recent, non-historic structures, the stations are larger and more modern looking. In Boston, the MBTA Silver Line Washington Street stations were modified based on community input to be more consistent with that corridor's historic brick architecture (Callaghan and Vincent 2008).

Exhibit 3-15 also shows that many U.S. systems have adopted clean propulsion technologies for their BRT vehicles. A majority of U.S. BRT systems have at least some vehicles powered with hybrid or CNG systems. While these propulsion systems can help reduce noise and vibration associated with frequent, high-capacity bus service, it should be noted that this is not always the case. Both Los Angeles and Boston experienced issues with their CNG buses creating vibration in the surrounding neighborhoods. The agencies addressed these problems with sound walls and vehicle modifications. It is far less common outside the U.S. to use alternative propulsion systems, although the European buses do employ very low emission diesel technologies.

Exhibit 3-15: BRT Elements by System and Contextual Design

City, State / Province / Country	Albuquerque	Boston Silver Line		
BRT Line / System	Rapid Ride	Washington St	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Running Way (miles)				
On Street Mixed Lanes	13.1	0.2	3.5	1.2
On Street Exclusive Bus Lanes	0.7	2.2		
Off Street Mixed Lanes		0.0		
Off Street Reserved Lanes		0.0		
At-Grade Transitway		0.0		
Grade-Separated Transitway		-	1.0	1.0
Queue Jumpers				
Marking	Signage	Signage and Striping		
Station				
Type	Enhanced Shelter	No Shelter, Basic Shelter, Enhanced Shelter & Transit Center	No Shelter, Underground Station & Transit Center	No Shelter, Underground Station & Transit Center
Access/Park & Ride Lots	2 lots	Pedestrian focus		90% arrive by public transit; 8% by walking
Vehicles				
Configuration	Articulated	Stylized Articulated	Articulated	Articulated
Floor Height	Low-floor	Low Floor	Low floor	Low-floor
Description of Livery / Image	Red & White Paint, Rapid Ride Logo	Special livery	Special livery	Special livery
Propulsion System and Fuel	Hybrid-Electric, ULSD	ICE CNG	Dual-Mode diesel & electric, ULSD	Dual-Mode diesel & electric, ULSD

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Chicago*			Cleveland
BRT Line / System	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Running Way (miles)				
On Street Mixed Lanes	18.3	9.0	9.4	2.7
On Street Exclusive Bus Lanes				4.4
Off Street Mixed Lanes				
Off Street Reserved Lanes				
At-Grade Transitway				
Grade-Separated Transitway				
Queue Jumpers				
Marking				Signage
Station				
Type	No Shelter	No Shelter	No Shelter	Enhanced Shelter
Access/Park & Ride Lots	0 lots	0 lots	0 lots	New bike path
Vehicles				
Configuration				Stylized articulated
Floor Height	Low	Low	Low	low
Description of Livery / Image	Distinct electronic destination signs	Distinct electronic destination signs	Distinct electronic destination signs	Specialized Livery, Large Windows
Propulsion System and Fuel				Hybrid diesel

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Eugene	Honolulu		
BRT Line / System	EmX	City Express: A	City Express: B	Country Express: C
Running Way (miles)				
On Street Mixed Lanes	1.4	19.0	8.0	18.0
On Street Exclusive Bus Lanes	2.6			
Off Street Mixed Lanes				3.5
Off Street Reserved Lanes				17.5
At-Grade Transitway				
Grade-Separated Transitway				
Queue Jumpers	Queue jump			
Marking	Raised delineators; concrete pavement, markings			Zipper Lane Concrete Barrier
Station				
Type	Enhanced Shelter, Station Building	Basic Shelter	Basic Shelter	Basic Shelter
Access/Park & Ride Lots	Pedestrian focus; bike lockers and racks	0 lots	0 lots	0 lots
Vehicles				
Configuration	Stylized articulated	Articulated	Standard	Articulated
Floor Height	low	Low	High	Low
Description of Livery / Image	Specialized Livery, Large Windows	Standard livery	Standard livery	Standard livery
Propulsion System and Fuel	Hybrid diesel	Diesel / Hybrid-Electric	Diesel	Diesel / Hybrid-Electric

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Kansas City	Las Vegas	Los Angeles	
BRT Line / System	MAX - Main St	MAX	Orange Line	Metro Rapid (All Routes)
Running Way (miles)				
On Street Mixed Lanes	6.0	3.0	1.0	229.5
On Street Exclusive Bus Lanes	along certain segments, for certain times of day	4.5	-	-
Off Street Mixed Lanes		-	0.0	0.0
Off Street Reserved Lanes		-	0.0	0.0
At-Grade Transitway		-	13.5	0.0
Grade-Separated Transitway		-		-
Queue Jumpers		1 queue jumper		Queue Jumpers
Marking	Bus Only Markings	Signage, Striping	At-Grade Busway, Signage at Intersections	
Station				
Type	Enhanced Shelter	Basic and Enhanced Shelter	Enhanced Shelter	No Shelter, Enhanced Shelter, Transit Center
Access/Park & Ride Lots	Pedestrian focus	Pedestrian focus	Majority arrive by transit, walking or bike. Bike path & pedestrian walkway. 7 park-and-ride lots.	Pedestrian focus
Vehicles				
Configuration	Stylized Standard	Stylized Articulated	Stylized Articulated	Stylized Standard and Articulated
Floor Height	Low floor	Low-floor	Low floor (15")	Low floor (15")
Description of Livery / Image	Max logo, unique livery and image, large continuous windows, sleek look	Sleek, modern lines with large windows	Silver metallic two-tone paint scheme & Metro Orange Line name branding, large windows	Red/Silver two-tone paint scheme & Metro Rapid name branding
Propulsion System and Fuel	ULSD	Diesel Electric Hybrid	ICE CNG	ICE CNG

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Miami	Oakland	Orlando*	Phoenix
BRT Line / System	Busway	San Pablo Ave Rapid	LYMMO	RAPID - I-10 East
Running Way (miles)				
On Street Mixed Lanes		14.0		6.5
On Street Exclusive Bus Lanes			-	
Off Street Mixed Lanes				
Off Street Reserved Lanes			-	14.0
At-Grade Transitway	20.0		3.0	-
Grade-Separated Transitway				
Queue Jumpers		Queue jumpers		
Marking	At-Grade Busway		Busway Barrier, Gray Pavers	Signage
Station				
Type	Enhanced Shelter	Basic Shelter	Enhanced Shelter	Enhanced Shelter
Access/Park & Ride Lots	6 lots; bike path	Pedestrian focus	Pedestrian focus, 1 lot	Commuter service; 250-500 car lots
Vehicles				
Configuration	Standard, Articulated, Minis	Stylized standard	Stylized standard	Specialized composite bus
Floor Height		Low	Low	Low
Description of Livery / Image	Standard Transit	Specialized Livery, Logos, Branding	Specialized Livery, Wide Doors	Distinct styling & livery
Propulsion System and Fuel	Hybrid, CNG, Diesel	Ultra-low-sulfur diesel	ICE CNG	LNG

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Phoenix			Pittsburgh*
BRT Line / System	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17	East Busway
Running Way (miles)				
On Street Mixed Lanes	4.8	12.3	8.0	
On Street Exclusive Bus Lanes				
Off Street Mixed Lanes				0.4
Off Street Reserved Lanes	8.0	10.3	11.5	-
At-Grade Transitway	-	-	-	
Grade-Separated Transitway				8.7
Queue Jumpers				
Marking	Signage	Signage	Signage	Grade Separated
Station				
Type	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter
Access/Park & Ride Lots	Commuter service; 250-500 car lots	Commuter service; 250-500 car lots	Commuter service; 250-500 car lots	16 lots
Vehicles				
Configuration	Specialized composite bus	Specialized composite bus	Specialized composite bus	Standard & Articulated
Floor Height	Low	Low	Low	
Description of Livery / Image	Distinct styling & livery	Distinct styling & livery	Distinct styling & livery	Standard and Articulated
Propulsion System and Fuel	LNG	LNG	LNG	Standard Diesel with 5 CNG

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Pittsburgh*		Sacramento	San Jose
BRT Line / System	South Busway	West Busway	EBus - Stockton	Rapid 522
Running Way (miles)				
On Street Mixed Lanes			8.0	25.0
On Street Exclusive Bus Lanes			0.0	0.0
Off Street Mixed Lanes	-	0.4	0.0	0.0
Off Street Reserved Lanes	-	-	0.0	0.0
At-Grade Transitway		4.6	0.0	0.0
Grade-Separated Transitway	4.3		None	-
Queue Jumpers			1 queue jumper	Queue Jumpers
Marking	Grade Separated	Busway	None	None
Station				
Type	Enhanced Shelter	Enhanced Shelter	No Shelter, Basic Shelter, Transit Center	No Shelter, Basic Shelter and Enhanced Shelter; Transit Center
Access/Park & Ride Lots	12 lots	10 lots		3 with 281 spaces. 3 existing lots with 1300 spaces at commuter rail stations
Vehicles				
Configuration	Standard & Articulated	Standard & Articulated		Stylized Standard and Articulated
Floor Height			Low-floor	Low floor (15")
Description of Livery / Image	Standard and articulated	Standard and articulated	Standard Branded	BRT-only full bus wraps
Propulsion System and Fuel	Standard Diesel with 5 CNG	Standard Diesel with 5 CNG	ICE CNG	ICE LSD

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Halifax	Ottawa		
BRT Line / System	MetroLink	95	96	97
Running Way (miles)				
On Street Mixed Lanes	12.1	2.1	2.1	2.1
On Street Exclusive Bus Lanes	0.5			
Off Street Mixed Lanes	10.6	3.2	13.1	5.2
Off Street Reserved Lanes	-	8.7	3.8	1.2
At-Grade Transitway	-	12.0	8.2	9.8
Grade-Separated Transitway	-			
Queue Jumpers				
Marking	Signage	Signage, Pavement Color	Signage, Pavement Color	Signage, Pavement Color
Station				
Type	Basic Shelter, Station Enclosures	Station Enclosures and Buildings	Station Enclosures and Buildings	Station Enclosures and Buildings
Access/Park & Ride Lots	6 lots			
Vehicles				
Configuration	Stylized Standard	Articulated	Standard	Articulated
Floor Height	Low floor	14.5 - 16"; 11.5" kneeling	14.5 - 16"; 11.5" kneeling	14.5 - 16"; 11.5" kneeling
Description of Livery / Image	Blue, yellow, white patterned livery and unique branding	Maple leaf livery; similar to rest of fleet	Maple leaf livery; similar to rest of fleet	Maple leaf livery; similar to rest of fleet
Propulsion System and Fuel	ICE Biodiesel	ICE Low-sulfur diesel	ICE Low-sulfur diesel	ICE Low-sulfur diesel

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	York		Bogota	Guayaquil
BRT Line / System	VIVA Blue	VIVA Purple	Transmilenio	Metrovia
Running Way (miles)				
On Street Mixed Lanes	20.3	17.1	-	-
On Street Exclusive Bus Lanes			-	-
Off Street Mixed Lanes			-	-
Off Street Reserved Lanes			-	-
At-Grade Transitway			52.0	10.0
Grade-Separated Transitway				
Queue Jumpers	Bus-Only Lanes at some intersections	Bus-Only Lanes at some intersections	-	-
Marking	None	None	Busway, Signage	Busway, Signage
Station				
Type	Basic and Enhanced Shelter	Basic and Enhanced Shelter	Station	Station
Access/Park & Ride Lots			No lots	No lots
Vehicles				
Configuration	Articulated	Standard	Stylized Articulated	Stylized Standard & Articulated
Floor Height	Low floor	Low floor	0.9 m	x
Description of Livery / Image	Metallic blue with Viva logo	Metallic blue with Viva logo	Red, branded articulated buses	Blue, branded articulated buses
Propulsion System and Fuel	ICE Clean diesel	ICE Clean diesel	Diesel; CNG pilot project underway with 3 buses	x

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Pereira	Amsterdam	Caen	Edinburgh
BRT Line / System	Megabus	Zuidtangent	Tram on Wheels	Fastlink
Running Way (miles)				
On Street Mixed Lanes	-	1.9		1.9
On Street Exclusive Bus Lanes	-	6.2	9.2	2.2
Off Street Mixed Lanes	-	2.5		-
Off Street Reserved Lanes	-	-		-
At-Grade Transitway	17.0	14.9	0.1	0.9
Grade-Separated Transitway				
Queue Jumpers	-	Queue Jumper		
Marking	Busway, Signage	Busway, Signage	Signage, concrete track with rail, landscaping	signage, color, segregation
Station				
Type	Station		Enhanced Shelters, Stations, Transit Centers	
Access/Park & Ride Lots	No lots			-
Vehicles				
Configuration	Stylized Articulated	Articulated	Bi-Articulated	Standard single and double deck
Floor Height	0.9 m	Low Floor	Low Floor	Low Floor
Description of Livery / Image	Green, branded articulated buses	Zuidtangent logo, red braded buses	Blue & White- Twisto	Standard
Propulsion System and Fuel	ICE diesel	Diesel	Dual Mode- Traction motor on-rail/ diesel engine off-rail	Diesel

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Eindhoven	Leeds	London	Rouen
BRT Line / System	Phileas - Western Corridor	Superbus	Crawley	TEOR
Running Way (miles)				
On Street Mixed Lanes	2.2	-	11.2	8.7
On Street Exclusive Bus Lanes		3.8	3.7	-
Off Street Mixed Lanes	-	-	-	-
Off Street Reserved Lanes	-	-	-	-
At-Grade Transitway	7.2	2.2	0.9	14.9
Grade-Separated Transitway				
Queue Jumpers			-	
Marking	Signage, concrete track, landscaping	Curb guidance, pavement markings, some pavement color	Signage, curb guidance	Color running way and slightly raised in downtown
Station				
Type				
Access/Park & Ride Lots		1 park-and-ride		1000 parking spaces
Vehicles				
Configuration	Articulated, Bi-Articulated	Standard	Standard	Articulated
Floor Height	Low Floor	Low Floor	Low Floor	Low Floor
Description of Livery / Image	Phileas bus logo	Standard	Fastway logo, blue/grey branded buses, unique enhanced shelters	TEOR Logo (Transport Est-Ouest Rouennais)
Propulsion System and Fuel	Hybrid (LPG/Electric)	Diesel	Diesel	Diesel

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Utrecht	Adelaide	Brisbane	
BRT Line / System	Busway	North East Busway	South East Busway	Inner Northern Busway
Running Way (miles)				
On Street Mixed Lanes	3.5			
On Street Exclusive Bus Lanes	2.0			
Off Street Mixed Lanes	-			
Off Street Reserved Lanes	-			
At-Grade Transitway	4.8			
Grade-Separated Transitway		7.46	10.3	1.7
Queue Jumpers				
Marking	Signage, pavement markings, pavement color	Off-Street Busway, Signage	Off-Street Busway, Signage	Off-Street Busway, Signage
Station				
Type		Transit Centers	Stations, Transit Centers	Stations, Transit Centers
Access/Park & Ride Lots		3 lots; 1,190 spaces	3 lots, 759 spaces	None Designated
Vehicles				
Configuration	Bi-Articulated	Standard Articulated = 60 Standard Rigid = 80	Standard Rigid	Standard Rigid
Floor Height	Low Floor	Merc - step high, Scania - step low floor	Mainly Step Low Floor Some Step High Floor	Mainly Step Low Floor Some Step High Floor
Description of Livery / Image	Standard	Standard white and yellow - same as non busway corridors	Standard Brisbane White, Blue and Yellow	
Propulsion System and Fuel	Diesel	Diesel	Mix of Diesel and CNG Gas Buses	Mix of Diesel and CNG Gas Buses

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Sydney			Beijing
BRT Line / System	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT
Running Way (miles)				
On Street Mixed Lanes				
On Street Exclusive Bus Lanes	6.0	0.3	1.9	
Off Street Mixed Lanes				2.2
Off Street Reserved Lanes				
At-Grade Transitway	13.0	4.4	8.7	8.1
Grade-Separated Transitway				
Queue Jumpers				
Marking	Signage, At-Grade Busway	Signage/Red Pavement Color; Busway	Signage/Red Pavement Color; Busway	Busway
Station				
Type	Basic and Enhanced Shelter; Stations	Stations, Transit Centers	Basic and Enhanced Shelters, Transit Centers	Stations
Access/Park & Ride Lots	1 Designated lot	None Designated	2 Designated Park and Ride lots	
Vehicles				
Configuration	Standard Rigid	Standard Rigid	Standard Rigid	Articulated
Floor Height	Step Low Floor	Step High	Step Mix Low Floor Step High	Low-Floor
Description of Livery / Image	Standard Sydney Bus Livery - Blue White and Yellow - with T-Way Logo	White Red Stripe	Yellow	Specialized BRT vehicles
Propulsion System and Fuel	Euro 3 diesel	Diesel	Diesel	

Exhibit 3-15: BRT Elements by System and Contextual Design (cont'd.)

City, State / Province / Country	Hangzhou	Kunming
BRT Line / System	Line B1	Busway network
Running Way (miles)		
On Street Mixed Lanes		
On Street Exclusive Bus Lanes	6.2	
Off Street Mixed Lanes		
Off Street Reserved Lanes		24.9
At-Grade Transitway		
Grade-Separated Transitway		
Queue Jumpers		
Marking	Striping	Striping
Station		
Type		
Access/Park & Ride Lots		
Vehicles		
Configuration	Articulated	Standard
Floor Height	Low-Floor	High-Floor
Description of Livery / Image	Specialized red BRT vehicles	
Propulsion System and Fuel		Diesel

PASSENGER SAFETY AND SECURITY

Safety and security are distinct, measurable attributes of a transit system that impact service attractiveness to customers, operating costs, and overall performance. They reflect different attributes that contribute to transit patron's comfort with riding a BRT system. Safety is the level of freedom from hazards experienced by passengers, employees, pedestrians, other vehicle occupants, and others who interact with the transit system. Security, meanwhile, is the level of the freedom from crime or other intentional danger experienced by transit employees, system users, and property. Implementation of BRT has the potential to yield improvements over conventional bus operations, such as:

- improved rider perception of safety and security - resulting from changes to physical design attributes and service characteristics - potentially inducing additional ridership
- reduced transit vehicle collisions with autos, objects, and pedestrians by minimizing interactions and potential conflicts within the travel right-of-way of other motor vehicles
- more predictable and manageable risks, which can reduce insurance claims, legal fees, and accident investigations
- reduced harm to passengers either from hazards or crime

The provision of a safe and secure environment for BRT customers requires careful consideration of the primary safety and security risks, and the best means to address those risks, within three key system environments: inside the vehicle, on the right-of-way, and at stations and stops. BRT stations and stops are of particular concern, as they are likely to be unattended and open during extended hours of operation. The sections below consider how investment in BRT can be expected to impact these risks, with safety and security issues discussed separately.

Safety

Description of Safety

Safety is the level of freedom from danger experienced by passengers, employees, pedestrians, occupants of other roadway vehicles, and others who interact with the transit system. In general, two performance measures reflect the quality of a transit agency's safety management: accident rates and public perception of safety. Accident rates can be measured by analyzing local agencies' historical collision records and nationally-reported transit accident data. The public perception of safety is often measured using passenger surveys or information gathered from other forms of customer feedback.

Effects of BRT Elements on Safety

Investment in many elements of BRT offers the potential to positively influence system safety performance relative to conventional bus operations. For example, as running way exclusivity increases, the frequency of sideswipe collisions between transit and non-transit vehicles decreases. At the same time, however, there is evidence to suggest that some systems with BRT characteristics may actually create conditions where specific types of safety hazards become more prominent. For example, different operating environments may experience higher rates of specific types of collisions, such as collisions at intersections and at-grade crossings. The following describes how specific BRT elements can impact safety performance and highlight safety issues that need to be addressed.

Running Way—Right-of-Way Location
Off-street running ways that involve the segregation of BRT vehicles from other traffic and from pedestrians may increase the level of safety and decrease the probability and severity of collisions by BRT vehicles, provided they address potential conflict points such as cross-street intersections and other at-grade vehicle and pedestrian crossings.
Running Way—Level of Running Way Priority
Creating running way priority through dedicated or exclusive facilities decreases potential conflict with traffic traveling in the same direction, thereby reducing potential for collisions caused by weaving and stopping.
Running Way—Markings
Running way markings can help decrease the likelihood of non-BRT vehicles entering an exclusive running way by visually differentiating the BRT running way from mixed-traffic streets.
Stations—Curb Design
Raised curbs or **level platforms** reduce the possibility of tripping and facilitate wheelchair and disabled person access.

Vehicles—Vehicle Configuration
The use of vehicle configurations with partial or complete low floors may potentially reduce tripping hazards for boarding BRT vehicles. Studies performed so far, however, cannot yet point to statistically-valid comparisons of passenger safety for low-floor buses versus high-floor buses. In implementing low-floor buses, hand-holds may be necessary between the entrance and the first row of seats since, in many cases, the wheel well takes up the space immediately beyond the entrance (King 1998).
ITS - Transit Vehicle Prioritization
Station and lane access control can improve security of transit facilities by providing access only to approved vehicles. Jurisdictions that implement signal priority should ensure that any bus-only signals are clearly marked and understood by other drivers.
ITS - Intelligent Vehicle Systems
Lane-keeping assistance systems, **collision warning systems**, **object detection systems**, and **precision docking** can contribute to the safety of a BRT system through smoother operation as it is operating at high speeds, in mixed traffic, or entering/exiting traffic flows. In addition, guidance technologies allow vehicles to follow a specified path along the running way and in approaches to stations, thereby helping operators to avoid collisions while maintaining close tolerances.

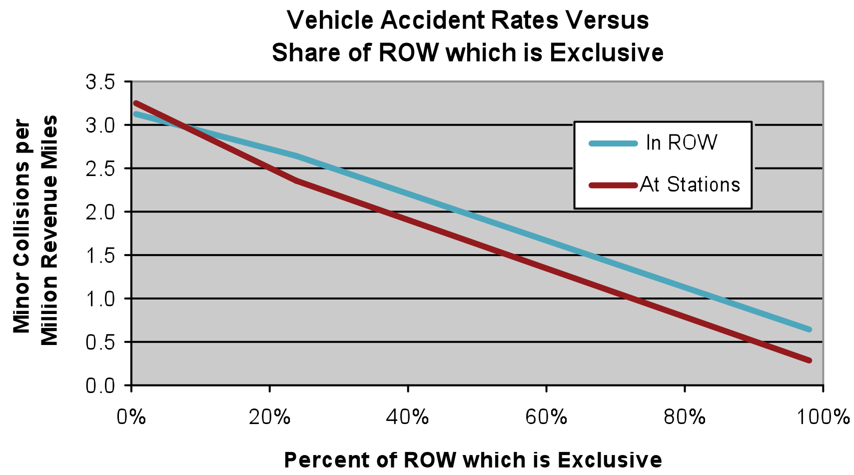
Performance of Existing Systems

Research Summary

On average, buses in conventional transit operations are subject to between one and two collisions per year, including collisions with other vehicles, pedestrians, and fixed objects, with an expected cost of roughly $5,000 per year per vehicle on collision-related expenses (including claims, damage repair, and insurance costs). To the extent that investment in BRT elements, most notably partial or exclusive running ways, can reduce either the incidence or severity of vehicle collisions, BRT investments can reduce collision costs, and riders may perceive this increased safety, potentially inducing additional ridership.

Given the small number of U.S. BRT systems and the short time period most systems have been in operation, the availability of domestic BRT system accident data remains limited, and the actual safety and security characteristics of BRT are not fully determined. However, a great deal of vehicle accident data are available on conventional bus, LRT, and other U.S. transit modes operating in mixed, partially-separated, and fully-exclusive rights-of-way. These data effectively demonstrate a key expected safety implication from investment in partially-separated or exclusive vehicle rights-of-way: vehicle collision rates, both on the right-of-way and at stations/stops, tend to decrease as the degree of running way "exclusivity" increases. This impact is clearly displayed in Exhibit 3-16.

Exhibit 3-16: Vehicle Accident Rates versus Share of Exclusive ROW



Source: National Transit Database (NTD), non-major bus and rail collisions, 2002 - 2005

The relationship presented in Exhibit 3-16 is representative of minor collisions (i.e., incidents resulting in minor injuries and/or vehicle damage). In contrast, the frequency and average severity of major collisions can actually increase when moving toward more exclusive running ways. Specifically, BRT and LRT systems have both experienced heightened collision rates and severities at points where exclusive running ways have at-grade roadway crossings (roughly 80 percent of LRT accidents occur at intersection crossings). These incidents are commonly the result of cross traffic, either running red lights or being unaware of the presence of the transit vehicle. System designers can address this important issue through improved crossing markings and warning systems.

System Performance Profiles

System profiles illustrate approaches to system safety in planning for BRT. The following profiles detail the experiences of new express busways in Miami and

Los Angeles, each of which illustrates the particular importance of grade crossings to BRT safety.

South Miami-Dade Busway

The design of traffic control, at crossings in particular, is an important determinant of system safety for BRT. After the initial 8.5-mile segment opened in February 1997, many serious collisions between BRT vehicles, motorists, and pedestrians occurred at the South Miami-Dade Busway's at-grade intersections. The proximity to the heavily travelled US-1 highway that parallels the busway contributed to safety conflicts. The frequency and seriousness of crashes at busway intersections between busway vehicles and vehicular traffic heightened attention to busway safety, particularly at several key intersections. Miami-Dade Transit (MDT) and Miami-Dade County installed extensive signage and signalization to deter such conflicts. MDT also revised operating procedures, requiring that busway vehicles proceed very slowly through busway intersections to minimize the risk of collision. MDT also has pursued changes to the *Manual on Uniform Traffic Control Devices* (MUTCD) to incorporate warrants that accommodate the installation of railroad-style crossing gates at intersections of BRT running ways and arterial streets.

Orange Line, Los Angeles

The Los Angeles Metro opened a dedicated busway with at-grade crossings, the Orange Line, in October 2005. During the first two months of operation, Orange Line vehicles were involved in 14 collisions, including 8 at crossings. In the following 10 months, there were another 13 collisions, 10 of which involved vehicle collisions at intersections. Metro instituted a number of measures to improve safety including:

- reducing Orange Line vehicles speeds through intersections from 25 to 10 mph
- installing 36-inch bus crossing signs at intersections
- changing traffic signal timing to give buses more time to clear intersections
- changing conventional round green signal indicators to an "up" arrow signal on the cross streets to emphasize the prohibition of "turning right on red"
- lowering the flashing "Bus Coming" sign to be immediately adjacent to "No Right Turn on Red" signs
- installing 24-in "Look Both Ways" pedestrian warning signs
- installing photo enforcement cameras to deter red-light runners
- adding "Keep Clear" pavement markings at intersections
- undertaking a major community education effort

By June 2006, following the implementation of these measures, the accident rate for the Orange Line was lower than that of other Metro services (Vincent and Callaghan 2007). This experience reinforces the notion that at-grade crossings are key focus areas for planners interested in ensuring safe operation of BRT systems. In addition, Metro's experience highlights the fact that at-grade systems are likely to experience safety issues soon after deployment, as motorists adjust to bus traffic in new corridors but they can be addressed through education efforts and clear intersection markings and signage. Nevertheless, the safety issues continue to require low speeds through intersections, reducing the Orange Line's average vehicle speed.

In summary, the safety performance of BRT systems is likely to depend on of the degree to which operating right-of-way is segregated from other traffic. At-grade crossings, in particular, represent a key area to be addressed during the development of a BRT system especially on segregated or off-street rights-of-way.

BRT Elements by System and Safety

Exhibit 3-17 presents a summary of BRT elements that are most relevant to passenger and system safety for BRT systems in 36 cities around the world, as well as any available performance data. Very few systems have reported any safety data, on either vehicle or passenger safety, so it is not possible to draw any statistically-significant relationships between elements and performance.

Following implementation of the Pittsburgh East Busway, bus accidents on this corridor were lowered—not surprising since the East Busway is fully grade-separated. However, passenger safety incidents increased; there was no clear explanation why this occurred. As already noted above, accidents on the Los Angeles Orange Line initially were a problem. However, recent performance data provided by Metro shows that the Orange Line has a much lower accident rate per mile than the Metro Rapid service, which operates in mixed traffic. Finally, the Boston Silver Line Waterfront Service has a lower vehicle accident and passenger injury rate than the MBTA system as whole. Again, it is not possible to draw any definitive conclusions about why this is, although it is worth noting that the portions of the Waterfront Service operate in an exclusive underground tunnel.

Many systems with off-street busways operate with at-grade intersection crossings, a feature that has been identified with increased accidents between buses and other vehicle traffic or pedestrians. Of the 27 BRT lines that have some off-street operation, 21 operate exclusively or partially with at-grade intersections. At-grade busways (such as the Miami South Dade Busway and Los Angeles Orange Line) are the predominant model in the U.S. (with the notable exception of Pittsburgh) and in Latin America. Europe typically features a mix of at-grade and fully-segregated off-street busway operations. However, the difference between Metro Rapid and Orange Line accident rates suggests that greater opportunities for accidents occur with buses operating in mixed traffic than in at-grade busways.

At this time, only Orlando, Phoenix, and Pittsburgh report having implemented collision warning systems. Vehicle docking guidance mechanisms, which may reduce passenger safety incidents, are very common in Europe, with most systems featured in Exhibit 3-17 indicating some type of guidance to minimize vehicle distance from loading platforms. Few other cities report using such guidance, although it should be noted that the three Latin American cities achieve virtually rail-like level boarding using non-mechanical guidance strategies.

Exhibit 3-17: BRT Elements by System and Safety

City, State / Province / Country	Albuquerque	Boston Silver Line		
BRT Line / System	Rapid Ride	Washington St	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Running Way (miles)				
On Street Mixed Lanes	13.1	0.2	3.5	1.2
On Street Exclusive Bus Lanes	0.7	2.2		
Off Street Mixed Lanes		0.0		
Off Street Reserved Lanes		0.0		
At-Grade Transitway		0.0		
Grade-Separated Transitway		-	1.0	1.0
Queue Jumpers				
Marking	Signage	Signage and Striping		
Station				
Curb Design	Standard Curb	Standard Curb	Standard Curb	Standard Curb
Vehicles				
Configuration	Articulated	Stylized Articulated	Articulated	Articulated
Floor Height	Low-floor	Low Floor	Low floor	Low-floor
ITS				
Transit Vehicle Prioritization	TSP	TSP - Green Extension, Red Truncation	No	No
Intelligent Vehicle Systems	None	None	None	none
Safety and Security			All 3 routes	All 3 routes
Measured Indicator of Safety (e.g. number of accidents)			5.86 accidents and .76 injuries per 100,000 vehicle miles; lower than systemwide	5.86 accidents and .76 injuries per 100,000 vehicle miles; lower than systemwide
Survey of Customer Perception of Safety or Security exists? (yes/no)		Yes	78% rated safety above average or excellent	78% rated safety above average or excellent

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Chicago*			Cleveland
BRT Line / System	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Running Way (miles)				
On Street Mixed Lanes	18.3	9.0	9.4	2.7
On Street Exclusive Bus Lanes				4.4
Off Street Mixed Lanes				
Off Street Reserved Lanes				
At-Grade Transitway				
Grade-Separated Transitway				
Queue Jumpers				
Marking				Signage
Station				
Curb Design	Standard Curb	Standard Curb	Standard Curb	Near Level
Vehicles				
Configuration				Stylized articulated
Floor Height	Low	Low	Low	low
ITS				
Transit Vehicle Prioritization				TSP
Intelligent Vehicle Systems				mechanical guidance
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Eugene	Honolulu		
BRT Line / System	EmX	City Express: A	City Express: B	Country Express: C
Running Way (miles)				
On Street Mixed Lanes	1.4	19.0	8.0	18.0
On Street Exclusive Bus Lanes	2.6			
Off Street Mixed Lanes				3.5
Off Street Reserved Lanes				17.5
At-Grade Transitway				
Grade-Separated Transitway				
Queue Jumpers	Queue jump			
Marking	Raised delineators; concrete pavement, markings			Zipper Lane Concrete Barrier
Station				
Curb Design	Raised platform	Standard Curb	Standard Curb	Standard Curb
Vehicles				
Configuration	Stylized articulated	Articulated	Standard	Articulated
Floor Height	low	Low	High	Low
ITS				
Transit Vehicle Prioritization	TSP			
Intelligent Vehicle Systems	Visual guidance			
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Kansas City	Las Vegas	Los Angeles	
BRT Line / System	MAX - Main St	MAX	Orange Line	Metro Rapid (All Routes)
Running Way (miles)				
On Street Mixed Lanes	6.0	3.0	1.0	229.5
On Street Exclusive Bus Lanes	along certain segments, for certain times of day	4.5	-	-
Off Street Mixed Lanes		-	0.0	0.0
Off Street Reserved Lanes		-	0.0	0.0
At-Grade Transitway		-	13.5	0.0
Grade-Separated Transitway		-		-
Queue Jumpers		1 queue jumper		Queue Jumpers
Marking	Bus Only Markings	Signage, Striping	At-Grade Busway, Signage at Intersections	
Station				
Curb Design	Raised Curb	Raised Curb	8" Curb	Standard Curb
Vehicles				
Configuration	Stylized Standard	Stylized Articulated	Stylized Articulated	Stylized Standard and Articulated
Floor Height	Low floor	Low-floor	Low floor (15")	Low floor (15")
ITS				
Transit Vehicle Prioritization	TSP	TSP		TSP
Intelligent Vehicle Systems		Optical Docking (not used)	None	None
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)		Accidents down 40% for MAX	avg = 1.45 accidents per 100,000 miles	avg = 4.83 accidents per 100,000 miles
Survey of Customer Perception of Safety or Security exists? (yes/no)				Passengers rate Metro Rapid Personal Safety on Buses 3.88 out of 5, compared to 3.40 for the former Limited Bus

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Miami	Oakland	Orlando*	Phoenix
BRT Line / System	Busway	San Pablo Ave Rapid	LYMMO	RAPID - I-10 East
Running Way (miles)				
On Street Mixed Lanes		14.0		6.5
On Street Exclusive Bus Lanes			-	
Off Street Mixed Lanes				
Off Street Reserved Lanes			-	14.0
At-Grade Transitway	20.0		3.0	-
Grade-Separated Transitway				
Queue Jumpers		Queue jumpers		
Marking	At-Grade Busway		Busway Barrier, Gray Pavers	Signage
Station				
Curb Design	Standard Curb	Standard Curb	Standard Curb	standard curb
Vehicles				
Configuration	Standard, Articulated, Minis	Stylized standard	Stylized standard	Specialized composite bus
Floor Height		Low	Low	Low
ITS				
Transit Vehicle Prioritization	No	TSP	TSP	TSP at 1 intersection
Intelligent Vehicle Systems			Collision warning, lane assist, precision docking	Collision Warning
Safety and Security	All 2004			
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)	67.5% of passengers rate safety riding vehicles as Good or Very Good; 59.5% of passengers rate safety at Busway stations as Good or Very Good (2004)	75% of customers rated personal safety on vehicles as good or very good; 72% rated safety at stations as good or very good.		

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Phoenix			Pittsburgh*
BRT Line / System	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17	East Busway
Running Way (miles)				
On Street Mixed Lanes	4.8	12.3	8.0	
On Street Exclusive Bus Lanes				
Off Street Mixed Lanes				0.4
Off Street Reserved Lanes	8.0	10.3	11.5	-
At-Grade Transitway	-	-	-	
Grade-Separated Transitway				8.7
Queue Jumpers				
Marking	Signage	Signage	Signage	Grade Separated
Station				
Curb Design	standard curb	standard curb	standard curb	Raised Curb
Vehicles				
Configuration	Specialized composite bus	Specialized composite bus	Specialized composite bus	Standard & Articulated
Floor Height	Low	Low	Low	
ITS				
Transit Vehicle Prioritization	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection	
Intelligent Vehicle Systems	Collision Warning	Collision Warning	Collision Warning	Collision Warning
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				Bus service in East Corridor experienced a 30% reduction in all accidents but a 6% increase in passenger accidents after implementation of the East Busway
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Pittsburgh*		Sacramento	San Jose
BRT Line / System	South Busway	West Busway	EBus - Stockton	Rapid 522
Running Way (miles)				
On Street Mixed Lanes			8.0	25.0
On Street Exclusive Bus Lanes			0.0	0.0
Off Street Mixed Lanes	-	0.4	0.0	0.0
Off Street Reserved Lanes	-	-	0.0	0.0
At-Grade Transitway		4.6	0.0	0.0
Grade-Separated Transitway	4.3		None	-
Queue Jumpers			1 queue jumper	Queue Jumpers
Marking	Grade Separated	Busway	None	None
Station				
Curb Design	Raised Curb	Raised Curb		Standard Curb
Vehicles				
Configuration	Standard & Articulated	Standard & Articulated		Stylized Standard and Articulated
Floor Height			Low-floor	Low floor (15")
ITS				
Transit Vehicle Prioritization		Signal Priority (magnetic loop sensors)	TSP - Green Ext	TSP - Green Extension, Red Truncation
Intelligent Vehicle Systems	Collision Warning	Collision Warning	None	None
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				No

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Halifax	Ottawa		
BRT Line / System	MetroLink	95	96	97
Running Way (miles)				
On Street Mixed Lanes	12.1	2.1	2.1	2.1
On Street Exclusive Bus Lanes	0.5			
Off Street Mixed Lanes	10.6	3.2	13.1	5.2
Off Street Reserved Lanes	-	8.7	3.8	1.2
At-Grade Transitway	-	12.0	8.2	9.8
Grade-Separated Transitway	-			
Queue Jumpers				
Marking	Signage	Signage, Pavement Color	Signage, Pavement Color	Signage, Pavement Color
Station				
Curb Design	Standard Curb	Standard Curb	Standard Curb	Standard Curb
Vehicles				
Configuration	Stylized Standard	Articulated	Standard	Articulated
Floor Height	Low floor	14.5 - 16"; 11.5" kneeling	14.5 - 16"; 11.5" kneeling	14.5 - 16"; 11.5" kneeling
ITS				
Transit Vehicle Prioritization	TSP	TSP	TSP	TSP
Intelligent Vehicle Systems	None	None	None	None
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)		Yes	Yes	Yes

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	York		Bogota	Guayaquil
BRT Line / System	VIVA Blue	VIVA Purple	Transmilenio	Metrovia
Running Way (miles)				
On Street Mixed Lanes	20.3	17.1	-	-
On Street Exclusive Bus Lanes			-	-
Off Street Mixed Lanes			-	-
Off Street Reserved Lanes			-	-
At-Grade Transitway			52.0	10.0
Grade-Separated Transitway				
Queue Jumpers	Bus-Only Lanes at some intersections	Bus-Only Lanes at some intersections	-	-
Marking	None	None	Busway, Signage	Busway, Signage
Station				
Curb Design	Standard Curb	Standard Curb	Level Platform	Level Platform
Vehicles				
Configuration	Articulated	Standard	Stylized Articulated	Stylized Standard & Articulated
Floor Height	Low floor	Low floor	0.9 m	x
ITS				
Transit Vehicle Prioritization	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction	x	x
Intelligent Vehicle Systems	None	None	none	None
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)			yes	

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Pereira	Amsterdam	Caen	Edinburgh
BRT Line / System	Megabus	Zuidtangent	Tram on Wheels	Fastlink
Running Way (miles)				
On Street Mixed Lanes	-	1.9		1.9
On Street Exclusive Bus Lanes	-	6.2	9.2	2.2
Off Street Mixed Lanes	-	2.5		-
Off Street Reserved Lanes	-	-		-
At-Grade Transitway	17.0	14.9	0.1	0.9
Grade-Separated Transitway				
Queue Jumpers	-	Queue Jumper		
Marking	Busway, Signage	Busway, Signage	Signage, concrete track with rail, landscaping	signage, color, segregation
Station				
Curb Design	Level Platform	Level platform	Level platform	Level platform
Vehicles				
Configuration	Stylized Articulated	Articulated	Bi-Articulated	Standard single and double deck
Floor Height	0.9 m	Low Floor	Low Floor	Low Floor
ITS				
Transit Vehicle Prioritization	x	RTSP	Signal Priority- Automatic	TSP
Intelligent Vehicle Systems	none	Only for Docking, Mechanical	Mechanical- Central Guidance Rail	Mechanical
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Eindhoven	Leeds	London	Rouen
BRT Line / System	Phileas - Western Corridor	Superbus	Crawley	TEOR
Running Way (miles)				
On Street Mixed Lanes	2.2	-	11.2	8.7
On Street Exclusive Bus Lanes		3.8	3.7	-
Off Street Mixed Lanes	-	-	-	-
Off Street Reserved Lanes	-	-	-	-
At-Grade Transitway	7.2	2.2	0.9	14.9
Grade-Separated Transitway				
Queue Jumpers			-	
Marking	Signage, concrete track, landscaping	Curb guidance, pavement markings, some pavement color	Signage, curb guidance	Color running way and slightly raised in downtown
Station				
Curb Design	Level platform	Level platform, Raised Curb	Standard Curb	Level Platform
Vehicles				
Configuration	Articulated, Bi-Articulated	Standard	Standard	Articulated
Floor Height	Low Floor	Low Floor	Low Floor	Low Floor
ITS				
Transit Vehicle Prioritization	TSP	Signal Priority in downtown areas		Signal Priority- Automatic and Manual
Intelligent Vehicle Systems	Electromagnetic docking (not in use)	Mechanical	Mechanical	Optical
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Utrecht	Adelaide	Brisbane	
BRT Line / System	Busway	North East Busway	South East Busway	Inner Northern Busway
Running Way (miles)				
On Street Mixed Lanes	3.5			
On Street Exclusive Bus Lanes	2.0			
Off Street Mixed Lanes	-			
Off Street Reserved Lanes	-			
At-Grade Transitway	4.8			
Grade-Separated Transitway		7.46	10.3	1.7
Queue Jumpers				
Marking	Signage, pavement markings, pavement color	Off-Street Busway, Signage	Off-Street Busway, Signage	Off-Street Busway, Signage
Station				
Curb Design	Level platform	Standard Curb	Standard Curb	Standard Curb
Vehicles				
Configuration	Bi-Articulated	Standard Articulated = 60 Standard Rigid = 80	Standard Rigid	Standard Rigid
Floor Height	Low Floor	Merc - step high, Scania - step low floor	Mainly Step Low Floor Some Step High Floor	Mainly Step Low Floor Some Step High Floor
ITS				
Transit Vehicle Prioritization	Signal Priority- Automatic	Passive Priority (No active)	-	-
Intelligent Vehicle Systems	-	Mechanical Guide Rollers on Front Axle	None	None
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)		yes	yes	yes

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Sydney			Beijing
BRT Line / System	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT
Running Way (miles)				
On Street Mixed Lanes				
On Street Exclusive Bus Lanes	6.0	0.3	1.9	
Off Street Mixed Lanes				2.2
Off Street Reserved Lanes				
At-Grade Transitway	13.0	4.4	8.7	8.1
Grade-Separated Transitway				
Queue Jumpers				
Marking	Signage, At-Grade Busway	Signage/Red Pavement Color; Busway	Signage/Red Pavement Color; Busway	Busway
Station				
Curb Design	Standard Curb	Standard Curb	Standard Curb	Level Platform
Vehicles				
Configuration	Standard Rigid	Standard Rigid	Standard Rigid	Articulated
Floor Height	Step Low Floor	Step High	Step Mix Low Floor Step High	Low-Floor
ITS				
Transit Vehicle Prioritization	Signal Pre-emption including green extension and early green	-	-	TSP
Intelligent Vehicle Systems	None	None	None	None
Safety and Security				
Measured Indicator of Safety (e.g. number of accidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)	yes			

Exhibit 3-17: BRT Elements by System and Safety (cont'd.)

City, State / Province / Country	Hangzhou	Kunming
BRT Line / System	Line B1	Busway network
Running Way (miles)		
On Street Mixed Lanes		
On Street Exclusive Bus Lanes	6.2	
Off Street Mixed Lanes		
Off Street Reserved Lanes		24.9
At-Grade Transitway		
Grade-Separated Transitway		
Queue Jumpers		
Marking	Striping	Striping
Station		
Curb Design	Standard Curb	Standard Curb
Vehicles		
Configuration	Articulated	Standard
Floor Height	Low-Floor	High-Floor
ITS		
Transit Vehicle Prioritization	TSP	
Intelligent Vehicle Systems	None	None
Safety and Security		
Measured Indicator of Safety (e.g. number of accidents)		
Survey of Customer Perception of Safety or Security exists? (yes/no)		

Security

Description of Security

The objective of passenger security is to minimize both the frequency and severity of criminal activities impacting BRT systems and their patrons. Reducing potential or perceived threats to employees, passengers, and property improves the image of BRT systems. Security performance measures generally are measured as crime rates experienced on the transit system per unit of output (e.g., per service hour or per trip). These statistics can then be compared to crime rates experienced in the system's surrounding areas or across the entire transit system.

Effects of BRT Elements on Security

Security principles should be studied and applied at all locations where passengers come into contact with BRT systems, specifically including stations and vehicles. Physical design elements, service characteristics, fare collection systems, and other advanced technologies all contribute to the level of passenger security.

Stations—Station Location
All off-street station locations and the on-street island platform station location separate passengers from pedestrians potentially protecting them from criminal elements on sidewalks. On-street curb-adjacent station locations do not. Design for on-street station types (curb-adjacent or island platform) need to protect passengers from exposure to motorists.
Stations—Station Type
Since passengers potentially can spend time at stations in an exposed environment, designing stations to minimize exposure to crime or security threats is important. Such considerations include the provision of clear or transparent materials to preserve sight lines through the facility, incorporation of security monitoring or emergency telephones, and barriers or fare-enforcement areas to deter non-patrons from entering the station area.
Vehicles—Aesthetic Enhancement
Aesthetic enhancements that support a secure environment emphasize visibility, brightness, transparency, and openness. Some vehicle characteristics that support these principles include **larger windows** and **enhanced lighting** to promote sight lines through the vehicle. Large windows in the front and rear of the vehicle reduce the presence of dim zones within the vehicle (Lusk 2007).

Fare Collection—Fare Collection Process
Off-board fare collection systems enhance security by promoting a vigilant security environment.
Proof-of-payment uses the same equipment, personnel, and procedures that are applied to collecting and enforcing fares and can help ensure passenger security on a system. Monitoring and surveillance measures could be applied to achieve both fare enforcement and security objectives. The presence of fare inspectors can both transmit a message of order and security and ensure a source of trained staff to assist customers in cases of emergency.
Barrier-enforced fare payment may discourage criminals from entering the system and targeting passengers with cash and may also provide a more secure or controlled environment for waiting passengers.
Fare Collection—Fare Media and Payment Options
Pre-paid instruments and passes may not enhance passenger security, but may be easier to control if lost or stolen and may discourage crime on the system because of the reduced number of transactions using cash. Fare media options such as **contactless smart cards** that allow for stored value and that do not require passengers to reveal the instrument while paying the fare may also enhance security. In addition, smart card data can be analyzed for fraudulent usage patterns to detect fare evaders and other criminals.
ITS—Operations Management
BRT security can be addressed with operations management technology such as **automated scheduling and dispatch** and **vehicle tracking**. In addition, **silent alarms** and **voice and video monitoring** are important to the security of the BRT vehicle and passengers. When criminal activity does occur, an integrated system that includes a silent alarm, video cameras, and vehicle tracking can alert dispatchers instantly to the status of the BRT vehicle, where it is located, and what is occurring on the BRT vehicle.
Service and Operating Plans
Service and operating plans that feature more frequent service on trunk lines minimize exposure of patrons to potential crime at stations by reducing time required to wait at stations.

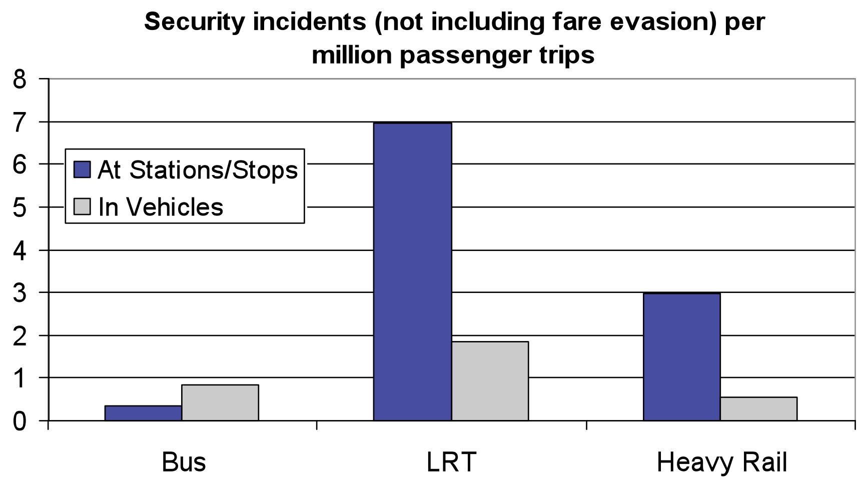
Performance of Existing Systems

Research Summary

As with system safety, the actual impact of domestic BRT investments on transit system security remains undetermined (due to the lack of available data). However, comparisons of security profiles among other existing transit modes allow for some estimation of the expected security performance of BRT.

Among existing transit modes, conventional bus service consistently reports the lowest overall crime rates, whether measured on a per passenger trip or vehicle revenue-mile basis. The higher crime reported for U.S. rail transit systems rates as compared to conventional bus, is primarily at stations and stops. (The majority of the reported crimes at stations and stops is burglary and theft related). These relationships are presented in Exhibit 3-18, which presents the number of security incidents per million passenger trips (including theft/burglary, property crimes, assaults, and suicides).

Exhibit 3-18: Security Incidents per Million Passenger Trips



Source: National Transit Database (NTD), major and non-major security incidents, 2002 - 2005

The reason for the higher reported crime rates among rail transit modes is unknown. However, several hypotheses may explain the differences. First, rail transit stations/stops and vehicles, especially those operating under proof-of-payment-based fare systems, are more commonly frequented by transit police as compared to conventional bus. Hence, incidents occurring on systems frequented by transit police are more likely to be reported, as compared to those modes transit police inspect with lower frequency. Moreover, crimes occurring at conventional bus stations are more likely to be reported to municipal police and not recorded by transit agencies, whereas crimes in LRT stations are more likely to be reported to transit police. These factors suggest that actual crime rates for conventional buses may be higher than reported crime rates. Nonetheless, the data suggest that reported crime is higher at rail stations and, by extension, BRT planners should adopt strategies to address this issue.

Enforcement of proof-of-payment systems is also important for maintaining low crime rates. Light rail transit systems have high rates of fare evasion relative to other transit modes due to the common use of proof-of-payment systems. There are nearly 200 recorded incidents of fare evasion per 1 million light rail passenger trips, compared to just 18 for commuter rail, 7 for heavy rail, and 2 for conventional buses. Prevention of fare evasion through information and enforcement is a critical component of proof-of-payment systems, such as those commonly promoted for BRT.

System Performance Profiles

Southeast Busway, Brisbane

The Southeast Busway is a two-way facility comprising elevated roadways and underground tunnels between the Brisbane CBD and communities to the southeast, terminating at Eight Mile Plains. Service continues through the Pacific Motorway to service Underwood and Springwood on the Gold Coast. It delivers fast and reliable bus services but also provides a safer public transport experience. A state-of-the-art Busway Operations Centre (BOC) at Woolloongabba plays a vital role in the management of the busway. Among other duties, staff at the BOC monitor security at stations and detect illegal use of the busway by unauthorized vehicles.

The 16.5 km busway route is monitored by 140 security cameras and patrolled 24 hours a day by Busway Safety Officers (BSO). All platforms are equipped with emergency telephones that link directly to the BOC. Real-time next bus information also is provided at stations to improve trip planning by passengers.

The stations use toughened glass screens to provide open and highly transparent spaces. Stations are well lit using high lux white lighting to improve visibility and station security. Pedestrian under- and over-passes improve the safety of crossing between platforms. Cautionary tactile paving is used throughout station entry plazas and platforms to assist the sight impaired. All stations are clearly signed, with entry plazas outlining safety tips and conditions of entry.

While there is a high frequency of bus service, there is a relatively low volume of vehicles on the busway since only buses and emergency vehicles are permitted on the facility. Lower travel volumes reduce the opportunities for collisions. Buses travel at 80 km/hr (50 mph) on the busway and 50 km/hr (31 mph) through busway stations when not stopping.

BRT Elements by System and Security

Exhibit 3-19 presents a summary of BRT elements that affect the security of the BRT systems in 36 cities around the world, as well as available performance data. In discussing security issues, it is important to distinguish between fare evasion and other security threats. Fare evasion is a non-violent offense, while most other security threats are violent or cause damage. Both types of threats can be generally addressed through physical design features (e.g., station and vehicle design and lighting), technological enhancements, surveillance, and enforcement. However, the specific techniques for reducing fare evasion are more straightforward to identify and implement.

Few systems provided data relating to system security, making it impossible to draw any conclusions about the impact of particular BRT elements on security. Several did report the results of passenger surveys that asked questions about safety and security perceptions. Many of these surveys asked passengers about their "personal safety," which could be interpreted as either security from crime or the likelihood of accidents. The following BRT systems reported the results of passenger surveys on safety:

- Boston Silver Line Waterfront Service: 78 percent of passengers rated safety above average or excellent.
- Los Angeles Metro Rapid: Passengers rated personal safety on buses 3.88 out of 5, compared to 3.40 for the former Limited Bus.
- Miami-Dade Busway: 67.5 percent of passengers rate safety riding vehicles as good or very good; 59.5 percent of passengers rate safety at busway stations as good or very good.
- AC Transit San Pablo Rapid: 75 percent of customers rated personal safety on vehicles as good or very good; 72 percent rated safety at stations as good or very good.

While it is not possible to draw broad conclusions from these few cases, it is interesting to note that each system has very different BRT elements, perhaps indicating that no single element is necessary to provide a feeling of security. For example, Boston's Silver Line Waterfront service features underground stations and the Miami busway has off-street enhanced shelters, while Metro Rapid and AC Transit Rapid have basic on-street stops.

Overall, many but not all of the BRT systems in Exhibit 3-19 report having either silent alarms, voice monitoring, or video monitoring to promote security. In addition, as noted earlier, most BRT systems are using modern stylized vehicles for their BRT services; these vehicles typically feature large windows and enhanced lighting, which may enhance a feeling of safety for passengers on the vehicle.

With regard to fare collection, only 10 cities report using proof-of-payment fare collection, which can reinforce a feeling of security because of the presence of agency personnel on the buses to check fares. This method is slightly more common in Europe, where five of the eight systems in Exhibit 3-19 use on-board payments in combination with proof-of-payment. Only Cleveland, Las Vegas, and the Los Angeles Orange Line use off-board proof-of-payment fare collection in the U.S.; all others use driver-based on-board fare collection or charge no fares at all. Of the 36 cities, only the three Latin American cities use barrier-controlled off-board payment systems, which can provide the highest level of security by controlling access to the system and requiring a heavy agency personnel presence at stations to check fares.

Exhibit 3-19: BRT Elements by System and Security

City, State / Province / Country	Albuquerque	Boston Silver Line		
BRT Line / System	Rapid Ride	Washington St	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Station				
Location	On-Street	On-Street	On and Off	On and Off
Type	Enhanced Shelter	No Shelter, Basic Shelter, Enhanced Shelter & Transit Center	No Shelter, Underground Station & Transit Center	No Shelter, Underground Station & Transit Center
Vehicles				
Configuration	Articulated	Stylized Articulated	Articulated	Articulated
Description of Livery / Image	Red & White Paint, Rapid Ride Logo	Special livery	Special livery	Special livery
Interior Features	Molded plastic with fabric inserts	Standard seats in 2+2 configuration	luggage racks for airport line	
Fare Collection				
Fare Collection Process	Pay on-board	Pay On-Board	Barrier at 3 underground stops; pay on board elsewhere	Barrier at 3 underground stops; pay on board elsewhere
Fare Media and Payment Options	Cash & Paper only	Cash / Paper Transfers / Magnetic Stripe / Smart Cards	cash, paper ticket, smart card	cash, paper ticket, smart card
ITS				
Automatic Vehicle Location (AVL)	GPS	GPS	GPS, dead reckoning in tunnel	GPS, dead reckoning in tunnel
Automated Scheduling and Dispatch		None	CAD	CAD
Vehicle Component Monitoring System		AVM		
Silent Alarms		x		
Voice and Video Monitoring	Video Monitoring	x		
Safety and Security			All 3 routes	All 3 routes
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)			78% rated safety above average or excellent	78% rated safety above average or excellent

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Chicago*			Cleveland
BRT Line / System	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Station				
Location	On	On	On	On
Type	No Shelter	No Shelter	No Shelter	Enhanced Shelter
Vehicles				
Configuration				Stylized articulated
Description of Livery / Image	Distinct electronic destination signs	Distinct electronic destination signs	Distinct electronic destination signs	Specialized Livery, Large Windows
Interior Features				Wide Aisles and Doors
Fare Collection				
Fare Collection Process	On Board	On Board	On Board	Off Board, Proof of Payment
Fare Media and Payment Options	Cash & Paper	Cash & Paper	Cash & Paper	
ITS				
Automatic Vehicle Location (AVL)				Yes
Automated Scheduling and Dispatch				
Vehicle Component Monitoring System				
Silent Alarms				Yes
Voice and Video Monitoring				
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Eugene	Honolulu		
BRT Line / System	EmX	City Express: A	City Express: B	Country Express: C
Station				
Location	On	On	On	On
Type	Enhanced Shelter, Station Building	Basic Shelter	Basic Shelter	Basic Shelter
Vehicles				
Configuration	Stylized articulated	Articulated	Standard	Articulated
Description of Livery / Image	Specialized Livery, Large Windows	Standard livery	Standard livery	Standard livery
Interior Features	Wide Aisles and Doors			
Fare Collection				
Fare Collection Process	None -- to be off board	Pay On-Board	Pay On-Board	Pay On-Board
Fare Media and Payment Options	N/A	Cash & Paper	Cash & Paper	Cash & Paper
ITS				
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	GPS
Automated Scheduling and Dispatch	CAD			
Vehicle Component Monitoring System				
Silent Alarms				
Voice and Video Monitoring				
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Kansas City	Las Vegas	Los Angeles	
BRT Line / System	MAX - Main St	MAX	Orange Line	Metro Rapid (All Routes)
Station				
Location	On	On and Off	Off	On and Off
Type	Enhanced Shelter	Basic and Enhanced Shelter	Enhanced Shelter	No Shelter, Enhanced Shelter, Transit Center
Vehicles				
Configuration	Stylized Standard	Stylized Articulated	Stylized Articulated	Stylized Standard and Articulated
Description of Livery / Image	Max logo, unique livery and image, large continuous windows, sleek look	Sleek, modern lines with large windows,	Silver metallic two-tone paint scheme & Metro Orange Line name branding, large windows	Red/Silver two-tone paint scheme & Metro Rapid name branding
Interior Features	Modern looking interior, increased aisle width, increase hip-to-knee room, wider doors, wider windows	modern auto like interior, finished window glazing	USSC Aries cloth seats	x
Fare Collection				
Fare Collection Process	Pay On-board	Proof-of-Payment	Proof-of-Payment	Pay On-board
Fare Media and Payment Options		Magnetic Stripe	Tickets from TVM and standard paper passes	Cash and Paper Passes
ITS				
Automatic Vehicle Location (AVL)	GPS	Orbital	GPS, Loop Detectors	GPS, Loop Detectors
Automated Scheduling and Dispatch		CAD/AVL	x	x
Vehicle Component Monitoring System		X	None	None
Silent Alarms			Yes	Yes
Voice and Video Monitoring		Yes	Automatic Transportation Monitoring System	Automatic Transportation Monitoring System
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				Passengers rate Metro Rapid Personal Safety on Buses 3.88 out of 5, compared to 3.40 for the former Limited Bus

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Miami	Oakland	Orlando*	Phoenix
BRT Line / System	Busway	San Pablo Ave Rapid	LYMMO	RAPID - I-10 East
Station				
Location	Off	On	Off	On
Type	Enhanced Shelter	Basic Shelter	Enhanced Shelter	Enhanced Shelter
Vehicles				
Configuration	Standard, Articulated, Minis	Stylized standard	Stylized standard	Specialized composite bus
Description of Livery / Image	Standard Transit	Specialized Livery, Logos, Branding	Specialized Livery, Wide Doors	Distinct styling & livery
Interior Features				high-back seating, forward facing, luggage racks, overhead lighting, reclining seats
Fare Collection				
Fare Collection Process	Pay on Board	Pay On-Board	Free	Pay On-Board
Fare Media and Payment Options	Cash, paper swipe card		Free	Cash, Magnetic Swiping
ITS				
Automatic Vehicle Location (AVL)	AVL	GPS	AVL/Wi-Fi	Orbital
Automated Scheduling and Dispatch	CAD	Yes	-	Yes
Vehicle Component Monitoring System	Yes		-	-
Silent Alarms	-		Yes	Yes
Voice and Video Monitoring	-	Yes	Yes	Yes
Safety and Security	All 2004			
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)	67.5% of passengers rate safety riding vehicles as Good or Very Good; 59.5% of passengers rate safety at Busway stations as Good or Very Good (2004)	75% of customers rated personal safety on vehicles as good or very good; 72% rated safety at stations as good or very good.		

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Phoenix			Pittsburgh*
BRT Line / System	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17	East Busway
Station				
Location	On	On	On	Off
Type	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter
Vehicles				
Configuration	Specialized composite bus	Specialized composite bus	Specialized composite bus	Standard & Articulated
Description of Livery / Image	Distinct styling & livery	Distinct styling & livery	Distinct styling & livery	Standard and Articulated
Interior Features	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats	high-back seating, forward facing, luggage racks, overhead lighting, reclining seats	Cushioned Seats
Fare Collection				
Fare Collection Process	Pay On-Board	Pay On-Board	Pay On-Board	Pay On-Board
Fare Media and Payment Options	Cash, Magnetic Swiping	Cash, Magnetic Swiping	Cash, Magnetic Swiping	Cash and Paper Only
ITS				
Automatic Vehicle Location (AVL)	Orbital	Orbital	Orbital	-
Automated Scheduling and Dispatch	Yes	Yes	Yes	-
Vehicle Component Monitoring System	-	-	-	-
Silent Alarms	Yes	Yes	Yes	-
Voice and Video Monitoring	Yes	Yes	Yes	-
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Pittsburgh*		Sacramento	San Jose
BRT Line / System	South Busway	West Busway	EBus - Stockton	Rapid 522
Station				
Location	Off	Off	On and Off	On and Off
Type	Enhanced Shelter	Enhanced Shelter	No Shelter, Basic Shelter, Transit Center	No Shelter, Basic Shelter and Enhanced Shelter; Transit Center
Vehicles				
Configuration	Standard & Articulated	Standard & Articulated		Stylized Standard and Articulated
Description of Livery / Image	Standard and articulated	Standard and articulated	Standard Branded	BRT-only full bus wraps
Interior Features	Cushioned Seats	Cushioned Seats	Standard	Typical transit bus - front facing, upholstered seats
Fare Collection				
Fare Collection Process	Pay On-Board	Pay On-Board	Pay on-board	Pay On-board
Fare Media and Payment Options	Cash and Paper Only	Cash and Paper Only	cash and passes	Cash and Paper Passes. Smart cards in development
ITS				
Automatic Vehicle Location (AVL)	-	-	None	GPS
Automated Scheduling and Dispatch	-	-	None	Trapeze
Vehicle Component Monitoring System	-	-	None	None
Silent Alarms	-	-	Yes	Yes
Voice and Video Monitoring	-	-	Yes	Yes, CCTV
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)				x
Survey of Customer Perception of Safety or Security exists? (yes/no)				No

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Halifax	Ottawa		
BRT Line / System	MetroLink	95	96	97
Station				
Location	On and Off	On and Off	On and Off	On and Off
Type	Basic Shelter, Station Enclosures	Station Enclosures and Buildings	Station Enclosures and Buildings	Station Enclosures and Buildings
Vehicles				
Configuration	Stylized Standard	Articulated	Standard	Articulated
Description of Livery / Image	Blue, yellow, white patterned livery and unique branding	Maple leaf livery; similar to rest of fleet	Maple leaf livery; similar to rest of fleet	Maple leaf livery; similar to rest of fleet
Interior Features	Cloth seats, reclining with arm / foot rests	Cloth seats	Cloth seats	Cloth seats
Fare Collection				
Fare Collection Process	Pay on-board	Proof-of-Payment	Proof-of-Payment	Proof-of-Payment
Fare Media and Payment Options	cash / tickets / passes	Cash, Paper tickets, or passes	Cash, Paper tickets, or passes	Cash, Paper tickets, or passes
ITS				
Automatic Vehicle Location (AVL)	AVL	GPS	GPS	GPS
Automated Scheduling and Dispatch	None	Yes	Yes	Yes
Vehicle Component Monitoring System	None	Under development	Under development	Under development
Silent Alarms	Yes, emergency button with operator	Yes	Yes	Yes
Voice and Video Monitoring	No	At stations, planned for in-vehicle	At stations, planned for in-vehicle	At stations, planned for in-vehicle
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)	x	x	x	x
Survey of Customer Perception of Safety or Security exists? (yes/no)	x	Yes	Yes	Yes

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	York		Bogota	Guayaquil
BRT Line / System	VIVA Blue	VIVA Purple	Transmilenio	Metrovia
Station				
Location	On and Off	On and Off	Off	Off
Type	Basic and Enhanced Shelter	Basic and Enhanced Shelter	Station	Station
Vehicles				
Configuration	Articulated	Standard	Stylized Articulated	Stylized Standard & Articulated
Description of Livery / Image	Metallic blue with Viva logo	Metallic blue with Viva logo	Red, branded articulated buses	Blue, branded articulated buses
Interior Features	Cloth seats in spacious arrangement and tables for workspace at some rear seats. WiFi being deployed. Large windows. Bright, large in-vehicle display screens	Cloth seats in spacious arrangement and tables for workspace at some rear seats. WiFi being deployed. Large windows. Bright, large in-vehicle display screens	molded plastic seats, front/rear and side facing	x
Fare Collection				
Fare Collection Process	Proof-of-Payment	Proof-of-Payment	Barrier (Verify at station entrances / exits)	Barrier
Fare Media and Payment Options	Paper tickets or passes	Paper tickets or passes	Smart Cards	Cash, Smart Cards
ITS				
Automatic Vehicle Location (AVL)	AVL-equipped	AVL-equipped	Loop detectors, station sensors	On-board transponders
Automated Scheduling and Dispatch	Yes	Yes	x	x
Vehicle Component Monitoring System	Oil temp, Oil pressure, Engine temp reported to control centre	Oil temp, Oil pressure, Engine temp reported to control centre	x	x
Silent Alarms	Yes, emergency button with covert alarm	Yes, emergency button with covert alarm	x	x
Voice and Video Monitoring	"No voice monitoring On-board video recording being installed, no monitoring"	"No voice monitoring On-board video recording being installed, no monitoring"	x	x
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)		x	x	x
Survey of Customer Perception of Safety or Security exists? (yes/no)			yes	x

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Pereira	Amsterdam	Caen	Edinburgh
BRT Line / System	Megabus	Zuidtangent	Tram on Wheels	Fastlink
Station				
Location	Off	On	On and Off	
Type	Station		Enhanced Shelters, Stations, Transit Centers	
Vehicles				
Configuration	Stylized Articulated	Articulated	Bi-Articulated	Standard single and double deck
Description of Livery / Image	Green, branded articulated buses	Zuidtangent logo, red braded buses	Blue & White- Twisto	Standard
Interior Features	molded plastic seats, front/rear and side facing		"bistro" style semi-circle seating at rear	
Fare Collection				
Fare Collection Process	Barrier (Verify at station entrances)	Pay On-Board or Proof of Payment	Pay On-Board or Proof of Payment	Pay On-Board or Proof of Payment
Fare Media and Payment Options	Smart Cards	Paper (Strippenkart)	Smart Cards, Magnetic tickets	Cash Coin (Exact Change) or Smart Card
ITS				
Automatic Vehicle Location (AVL)	On-board transponders			GPS
Automated Scheduling and Dispatch	x			Yes
Vehicle Component Monitoring System	x			
Silent Alarms	x			
Voice and Video Monitoring	x			CCTV at station and in bus
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)	x			
Survey of Customer Perception of Safety or Security exists? (yes/no)	x			

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Eindhoven	Leeds	London	Rouen
BRT Line / System	Phileas - Western Corridor	Superbus	Crawley	TEOR
Station				
Location				
Type				
Vehicles				
Configuration	Articulated, Bi-Articulated	Standard	Standard	Articulated
Description of Livery / Image	Phileas bus logo	Standard	Fastway logo, blue/grey branded buses, unique enhanced shelters	TEOR Logo (Transport Est-Ouest Rouennais)
Interior Features				
Fare Collection				
Fare Collection Process	Proof-of-Payment, Pay On-Board machine, no driver payment	Pay On-Board	Pay On-Board	Off-board Fare Collection
Fare Media and Payment Options	Paper (Strippenkart)	Cash and Paper Only	Cash	Magnetic Strip
ITS				
Automatic Vehicle Location (AVL)				
Automated Scheduling and Dispatch				
Vehicle Component Monitoring System				
Silent Alarms				
Voice and Video Monitoring				
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)				
Survey of Customer Perception of Safety or Security exists? (yes/no)				

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Utrecht	Adelaide	Brisbane	
BRT Line / System	Busway	North East Busway	South East Busway	Inner Northern Busway
Station				
Location		Off	Off	Off
Type		Transit Centers	Stations, Transit Centers	Stations, Transit Centers
Vehicles				
Configuration	Bi-Articulated	Standard Articulated = 60 Standard Rigid = 80	Standard Rigid	Standard Rigid
Description of Livery / Image	Standard	Standard white and yellow - same as non busway corridors	Standard Brisbane White, Blue and Yellow	
Interior Features		Luggage racks over wheel hubs		
Fare Collection				
Fare Collection Process	Proof-of-Payment, Pay On-Board	Pay on Board (80% pre pay multi-rider ticket)	Pay on Board	Pay on Board
Fare Media and Payment Options	Paper (Strippenkart)	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe	
ITS				
Automatic Vehicle Location (AVL)		-	GPS	GPS
Automated Scheduling and Dispatch		X	X	X
Vehicle Component Monitoring System		X	X	X
Silent Alarms		Yes	-	-
Voice and Video Monitoring		Yes	Yes	Yes
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)		-	-	-
Survey of Customer Perception of Safety or Security exists? (yes/no)		yes	yes	yes

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Sydney			Beijing
BRT Line / System	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT
Station				
Location	On and Off	Off	On and Off	Off
Type	Basic and Enhanced Shelter; Stations	Stations, Transit Centers	Basic and Enhanced Shelters, Transit Centers	Stations
Vehicles				
Configuration	Standard Rigid	Standard Rigid	Standard Rigid	Articulated
Description of Livery / Image	Standard Sydney Bus Livery - Blue White and Yellow - with T-Way Logo	White Red Stripe	Yellow	Specialized BRT vehicles
Interior Features				
Fare Collection				
Fare Collection Process	Pay on Board	Pay on Board	Pay on Board	Pay attendants at station
Fare Media and Payment Options	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe	Cash & Paper Magnetic Stripe	Cash / Smart Cards
ITS				
Automatic Vehicle Location (AVL)	Loop Detectors			Yes
Automated Scheduling and Dispatch	X	X	X	
Vehicle Component Monitoring System	X	X	X	
Silent Alarms	-	-	-	
Voice and Video Monitoring	Yes	Yes	Yes	X
Safety and Security				
Measured Indicator of Security (e.g. number of incidents)	-	-	-	
Survey of Customer Perception of Safety or Security exists? (yes/no)	yes			

Exhibit 3-19: BRT Elements by System and Security (cont'd.)

City, State / Province / Country	Hangzhou	Kunming
BRT Line / System	Line B1	Busway network
Station		
Location	On	
Type		
Vehicles		
Configuration	Articulated	Standard
Description of Livery / Image	Specialized red BRT vehicles	
Interior Features		
Fare Collection		
Fare Collection Process	Pay at station	Pay On-Board
Fare Media and Payment Options	Cash / Smart Cards	Cash / IC Cards
ITS		
Automatic Vehicle Location (AVL)	Yes	
Automated Scheduling and Dispatch		
Vehicle Component Monitoring System		
Silent Alarms		
Voice and Video Monitoring		
Safety and Security		
Measured Indicator of Security (e.g. number of incidents)		
Survey of Customer Perception of Safety or Security exists? (yes/no)		

SYSTEM CAPACITY

System capacity refers to the maximum number of people or transit vehicles that can be moved past a point by a BRT line or system. In practice, there are few corridors outside the nation's largest metropolitan areas where capacity constraints are an issue. As passenger demand for a particular BRT line begins to meet or exceed capacity at its critical points, it is likely to impact the quality of service: reliability suffers, operating speeds decrease, and passenger loads increase. Therefore, providing adequate capacity for BRT systems is essential.

There are three key issues for BRT system capacity assessment:

- **BRT system capacity is limited by the critical link or lowest-capacity element (e.g., the bottleneck) within the BRT system.** Three key elements determine BRT system capacity: BRT vehicle (passenger) capacity, BRT station (vehicle and passenger) capacity, and BRT running way (vehicle) capacity. Whichever of these is the most constraining on throughput becomes the controlling factor for the entire BRT corridor.
- **There is a difference between** *capacity* **of a BRT system and the** *demand* **placed upon a BRT system.** Capacity is a measure of the estimated maximum number of passengers that *could* be served by a particular BRT line. Demand is the *actual* number of passengers utilizing the line. The volume (demand) to capacity ratio is a standard measure to determine capacity utilization.
- **Capacity and BRT level-of-service (LOS) are interdependent**. LOS parameters effecting capacity include the availability of service (measured as frequency, span and coverage), the level of comfort (e.g., measured as standee density), travel time, and reliability.

In presenting capacities of various BRT systems, person capacity will be expressed in terms of the theoretical maximum number of passengers that can be carried past the maximum load point along a BRT route per hour. It is important to note that the actual capacity (operated capacity) may actually be less than the maximum person capacity because BRT systems often operate at frequencies lower than the theoretical maximum capacity.

The remainder of this section provides a detailed account of how BRT system capacity is calculated (much of the information has been distilled from the *Transit Capacity and Quality of Service Manual, 2nd Edition*), summarizes how each BRT element affects BRT system capacity, and provides examples of the capacity of existing BRT systems.

Description of Person Capacity

For BRT systems, the most appropriate measure of capacity is a concept called person capacity. Person capacity is defined by the *Transit Capacity and Quality of Service Manual, 2nd Edition* as:

> the maximum number of passengers that can be carried along the critical section of the BRT route during a given period of time, under specified operating conditions, without unreasonable delay, hazard, or restriction and with reasonable certainty

When discussing capacity, there are two key points to emphasize that capacity has multiple dimensions. How much capacity a system is designed to accommodate or how much capacity is operated are not necessarily equal to the maximum capacity or to each other. Three dimensions are useful to consider: maximum capacity, design capacity, and operated capacity. The differences are explained in Exhibit 3-20.

Exhibit 3-20: Different Aspects of Capacity

Dimension of Capacity	Definition	Determined by
Maximum Capacity	The unconstrained theoretical maximum capacity as determined by the physical characteristics of the system.	Vehicle size (maximum) BRT facility
Design Capacity	Maximum capacity scaled down due to standards and policies (constraints) related to passenger comfort, safety, and manageability.	Operating policies
Operated Capacity	The capacity based on the vehicle size and frequency actually operated. The operated capacity is usually less than the maximum capacity since the operation is scaled to actual demand.	Service plan (frequency) Vehicle size (actual; size may be smaller than the system can handle)

Effects of BRT Elements on Person Capacity

Different BRT elements determine the three different aspects of capacity described above.

Maximum Person Capacity

Three primary factors determine the maximum person capacity—passenger capacity of BRT vehicles (how many passengers a vehicle can carry), the vehicle capacity of BRT facilities, and passenger demand characteristics. The influence of each factor on the system's overall person capacity of a system is explained in more detail below.

Passenger capacity of BRT vehicles denotes the maximum number of seated and standing passengers that a vehicle can safely and comfortably accommodate. Other vehicle characteristics such as overall length and the number and width of doors also influence dwell times and the BRT facility capacity.

Vehicle capacity of BRT facilities defines the number of vehicles per hour that can use a specific BRT facility. This is largely driven by characteristics and resultant capacities of the BRT system running ways, stations, and the vehicles themselves. For both running ways and stations, capacity is enhanced by strategies and design elements that both increase the size of the system (e.g., multiple running way lanes, bus pullouts, larger stations) and reduce delays and improve the service rate of the system (e.g., transit prioritization systems, access control, strategies to reduce running time and dwell time). Average operating speeds and dwell times also influence the vehicle capacity of BRT facilities, and these characteristics are largely functions of the type and performance of the vehicles themselves.

Unlike other performance attributes, where the performance is determined by the sum of individual elements, capacity is determined by the most constrained element. While individual elements of a BRT system (vehicles, station loading areas, entrances to vehicles, running way lanes) have individual capacities, BRT system capacity is determined by the bottlenecks in the system or by the components that have the lowest person capacity. For example, there may be plenty of capacity on the running way, but if BRT vehicles back up because prior vehicles are still loading or unloading at the station, the BRT vehicle loading area capacity at the station defines the maximum number of persons that the system can carry.

Passenger demand characteristics affect capacity by defining where the maximum load points (potential bottlenecks) in the system are and by affecting loading/unloading times. Key passenger demand characteristics include:

- **Distribution of passengers over time**—the more even the distribution of passengers, the higher the system capacity. Concentrated, uneven loads create bottlenecks that reduce capacity.
- **Passenger trip length**—long trip lengths decrease the number of passenger trips that can be accommodated with a given schedule.
- **Distribution of boarding passengers (and alighting) among stations**—high concentrations of passengers at stations drive the maximum dwell time which reduces the number of vehicles a system can carry.

Design Capacity

Operators often define loading and service frequency standards for various types of service and/or vehicles that are below the theoretical maximum. Examples of such standards relate to:

- **Comfort** (loading standards, standee policies)—some services (especially premium park-and-ride or express service) may have passenger loading standards or policies allowing no standees. Such policies are designed to promote passenger comfort.
- **Safety** (minimum spacing, limits on overtaking, speed limits)—the frequency of service may be set at one vehicle every 5 or 10 minutes, even though the facility can accommodate much more frequent service based upon safe sight and stopping distances, and other traffic engineering concerns.
- **Manageability** (minimum headway, schedule recovery policies)—operator policies may indicate stable headways can be maintained with a specific minimum headway or with provision for longer recovery time in the schedule

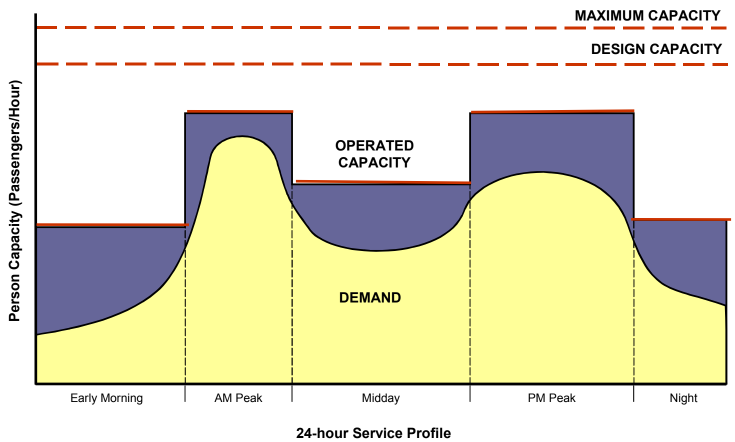
When these policy constraints are factored in, a lower "design" person capacity for the system results.

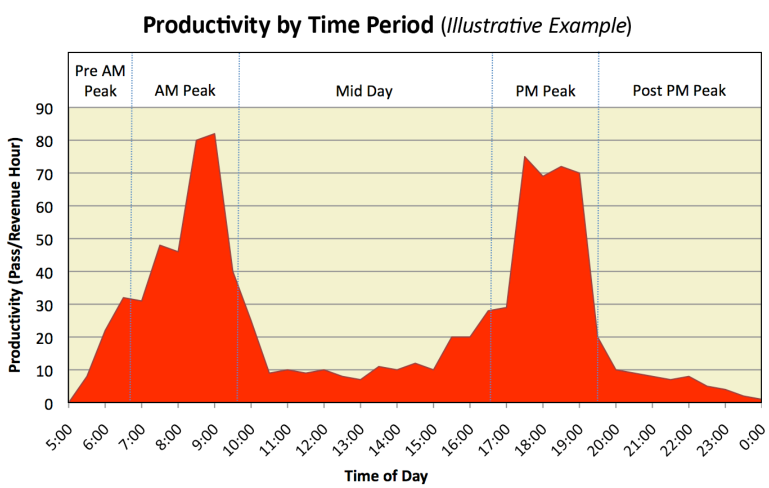
Operated Capacity

The realistic determinant of actual capacity is the frequency of service and the size of the actual vehicles operated. Because passenger demand often does not reach the maximum capacity of the system, BRT systems operate at lower frequencies or with smaller vehicles than the system can accommodate to match demand. As demand grows, frequency and vehicle size can be increased to meet demand and take advantage of any unused capacity.

Exhibit 3-21 illustrates temporal demand for transit services. The first image is based on actual passenger volume data taken from a rail transit operator. The second image illustrates the general relationship between demand and operated capacity. They illustrate the need to assess capacities for the peak of demand as well as immediately before and after each peak (the "shoulders" of the peak).

Exhibit 3-21: Temporal Demand for Rail Transit Service





The contribution of each BRT element to each aspect of capacity is summarized in Exhibit 3-22 and discussed in the remainder of this section.

Exhibit 3-22: Relationship of BRT Elements to Aspects of Person Capacity

Capacity Factor	Elements Affecting How Many Passengers Can Be Carried in a Vehicle (Passenger Capacity of Vehicles)	Maximum Capacity: Elements Affecting How Many Vehicles the BRT System Can Process (Vehicle Capacity of BRT Facilities) — Affect the Size of Vehicles That Can Be Accommodated	Maximum Capacity: Elements Affecting How Many Vehicles the BRT System Can Process (Vehicle Capacity of BRT Facilities) — Affect How Quickly Vehicles Pass Through the System	Operated Capacity—Elements Affecting What Capacity is Actually Operated
BRT Element				
Running Ways		x	x	
Stations		x	x	
Vehicles	x		x	x
Fare Collection			x	
ITS			x	
Service and Operations Plan				x

Running Ways—Running Way Type

Increasing the level of segregation of the running way through use of **designated lanes, at-grade exclusive lanes**, and **grade-separated exclusive lanes** reduces the number of non-BRT or non-transit vehicles that can use the facility and also reduces the conflicts with parallel and crossing traffic. This increases the number and frequency of transit vehicles that each lane can accommodate. In many cases, BRT systems combine multiple types of running ways. In these cases, the running way capacity is limited by the running way section that can accommodate the lowest volume of vehicles. Effectively, the person capacity of a running way is limited by its least exclusive section.

Stations—Station Type

Factors that can influence the service time of a station (time between when a BRT vehicle enters and exits the station) include:

- adequate capacity for bus bays/berths/loading areas
- real-time passenger information to reduce passenger/operator interaction time (ITS)
- off-board fare collection
- station capacity and layout/design to allow multi-door boarding

Stations—Curb Design

Raised curbs and **level platforms** increase capacity by facilitating the boarding and alighting process for all passengers, and are especially beneficial to the elderly, youth, and passengers with disabilities.

Stations—Platform Layout

Extended platforms accommodate more vehicles, thereby increasing the number of passengers that can load simultaneously

Stations—Passing Capability

Stations with extra-wide running way to allow for vehicles to pass stopped, delayed, or disabled vehicles can eliminate bottlenecks in the BRT system.

Vehicles—Vehicle Configuration

Longer buses, such as **articulated vehicles**, have higher person capacity by as much as 50 percent over standard 40-ft buses through a combination of seated and standing passengers. The doors, floors and capacity of typical length buses are illustrated in Exhibit 3-23.

ITS—Transit Vehicle Prioritization

Vehicle prioritization technologies—including **signal timing/phasing**, **transit signal priority**, **station and lane access control**—reduce conflicts with other traffic and potential delays to BRT vehicles along the running way and at station entrances and exits. Intermittent access control of bus lanes, such as those demonstrated in Portugal, offer the opportunity to share ROW with other vehicles, while preserving the capacity necessary for BRT operations.

ITS—Intelligent Vehicle Systems

Driver assist and automation strategies increase the potential frequency of transit service and reduce the overall time per stop. **Collision avoidance** and **lane assist** allow vehicles to safely operate closer together and also allow BRT vehicles to re-enter the flow of traffic more quickly and safely. **Precision docking** will allow a BRT vehicle to precisely and consistently stop in the same location each time, speeding up the approach and departure of a vehicle from a station and reducing overall dwell time since passengers will know exactly where to line up to board.

ITS—Operations Management Systems

Automated scheduling and dispatch systems allow a higher frequency of BRT vehicles and facilitate response to incidents that create bottlenecks. **Vehicle tracking** reduces the failure rate of BRT vehicles arriving at the BRT Station.

Service and Operations Plan—Service Frequency

Service frequency is one of the key determinants of operated capacity. Increasing frequency provides more passenger spaces in the same amount of time. Note, however, that it does not change the maximum passenger capacity of the system.

Service and Operations Plan—Operating Procedures

Other elements of service and operations plans can affect the way that capacity is deployed to match passenger demand. Some elements that affect capacity are:

- mandated minimum and maximum operating speeds—e.g., slowing at intersections on busways, station approach speeds
- policies on standees (passenger loading standards)
- yield to buses when leaving stations
- policies related to loading disabled passengers and bicycles
- enforcement of policies prohibiting non-BRT vehicles from the running way
- other transit service and capacity in the same corridor (especially during the peak period)

Exhibit 3-23: Typical U.S. and Canadian BRT Vehicle Dimensions and Capacities

Length (ft)	Width (ft)	# Door Channels	# Seats (incl. seats in wheel chair tie-down areas)	Maximum Capacity* (seated plus standing)
40 (12.2 m)	96-102 (2.45-2.6m)	2-5	35-44	50-60
45 (13.8 m)	96-102 (2.45-2.6m)	2-5	35-52	60-70
60 (18 m)	98-102 (2.5-2.6m)	4-7	31-65	80-90
80 (24 m)	98-102 (2.5-2.6m)	7-9	40-70	110-130

Capacity includes seated riders plus standees computed at a density of 3 standing persons per square meter.

Performance of Existing Systems

Research Summary

The capacity of BRT running ways on arterials can vary greatly based on the design and operation of running ways. A survey of running ways presented in Exhibit 3-24 of transitways around the world shows that the frequency of vehicles can reach 200 to 300 vehicles per hour. This demonstrates that capacities for BRT systems can reach levels beyond the capacity needs of most developed urban corridors. Most systems in North America do not reach these levels of demand, and, therefore, do not demonstrate operation near maximum capacity.

Exhibit 3-24: Maximum Observed Peak Hour Bus Flows, Capacities, and Passenger Flows at Peak Load Points on Transitways

Type of Running Way	Cities Applied	Measured Peak Hour Vehicle Flows (veh/hr)	Measured Peak Hour Passenger Flow (passengers/hr)	Estimated Practical Capacity (passengers/hr)
Designated Lane	Ankara, Istanbul, Abidjan	91 - 197	7,300 - 19,500	5,800 – 18,100
Designated Lanes with Feeders	Curitiba	94	9,900	13,900 – 24,100
Designated Lanes with Bus Ordering (Traveling in Clusters)	Porto Alegre (2 separate facilities)	260 - 304	17,500 - 18,300	8,200-14,700
Designated Lanes with Overlapping Routes, Passing at Stations and Express Routes	Belo Horizonte, Sao Paolo	216 - 221	15,800 -20,300	14,900 – 27,900

System Performance Profiles

Martin Luther King Jr. East Busway, Pittsburgh

Planners at the Port Authority estimate that the Martin Luther King Jr. East Busway can accommodate 1 vehicle every 24 seconds or a total of 150 vehicles per hour. Assuming the maximum-size vehicle that can be accommodated, an articulated vehicle with 63 places, the maximum person capacity of the facility is 9,450 passengers per hour.

RAPID, Phoenix Public Transit Department

The experience of the Phoenix RAPID system demonstrates how the service frequency defines the operated capacity of a BRT system. When the RAPID system first began operation, it operated a limited number of trips oriented toward the commute market. Furthermore, the Phoenix Public Transit Department used buses specially built for the commuter-type service it was operating that indicated passengers would have a comfortable high-back, reclining seat. Hence, the Phoenix Public Transit Department, through its policy of limiting standees, reduced the overall capacity of each bus to a specified design capacity.

As the RAPID service continued and external events impacted potential riders (e.g., rising gas prices, pollution, and urban congestions), demand began to exceed the pre-determined operated capacity, which resulted in many riders having to stand for trips during the peak periods. While the RAPID system could have continued operating with standees, the comfort of the passengers (e.g., seat availability) was a critical element in the design of the system. Four additional trips were added during the peak periods to add seat availability, thus increasing operated capacity of the system.

Curitiba

Curitiba's BRT system has served as the model for many BRT systems and continues to be one of the world's highest-performing BRT systems. One exceptional performance measure is capacity: the 54-km system carries 15,000 riders per hour at peak times. City planners began designing the BRT system in the late 1960s as part of a Master Plan to channel growth around high-capacity transit corridors. Today, 70 percent of commuters use the transit system daily in a city with a metro area population of over 2.7 million. To accommodate this demand, the BRT system operates on dedicated bus lanes along five corridors radiating out from the city center. Intersections are equipped with signal priority, and express service is provided on one-way streets located one block on either side of BRT artery routes. Stations have multiple-vehicle platforms with level boarding and automated doors at the interface between vehicles and stations. Almost 2,000 articulated buses serve the BRT network at headways of as little as 90 seconds (a capacity of 40 buses per direction per hour).

Line 1 BRT, Beijing

Beijing's first BRT line offers an example of how to address overcapacity. The BRT service was designed to alleviate congestion and reduce travel times in the 10-mile corridor. The 10.3-mile route features an 8.1-mile dedicated median busway, with grade separations at some intersections, and 2.2 miles of off-street mixed lanes. To improve travel times further and offer high capacity, the government implemented transit signal priority, off-board fare collection, and articulated vehicles with three double left-side doors. There is also a marketing program with brochures and signs at stations to help passengers understand the system. In order to direct passengers to the BRT and rationalize transit operations, three regular bus routes were eliminated and two were shortened to act as BRT feeders. In all, the BRT project eliminated 300 standard buses per direction per hour in the corridor. While this saved the operator money, it also contributed to significant overcrowding, with ridership reaching 100,000 per day. To reduce overcrowding, the operator restored a parallel bus route and added 25 regular buses during peak hours. Ridership on the BRT dropped to 85,000 per day, with a peak hour ridership of around 7,500 per direction. Twenty new BRT buses were added in April 2006 to accommodate demand.

BRT Elements by System and Person Capacity

Exhibit 3-25 presents a summary of BRT elements that affect capacity for BRT systems in 36 cities around the world, and available performance measures. The primary performance measure provided is:

Maximum Critical Link Throughput (persons per direction per hour)—this measurement is based on the maximum number of vehicles operated per hour multiplied by a vehicle's maximum capacity. (Note: In the case of this data table, the Maximum Critical Throughput figure was provided directly by the transit agency.)

A comparison of the Maximum Critical Link Throughput data provided supports the theory that vehicle capacity, station capacity and running way capacity are the primary elements impacting total person capacity for a BRT system. The other element that strongly correlates with maximum throughput is frequency of service. Maximum capacity results from a combination of these elements, rather than any one element being the dominant determinant. In general, as systems add one more element of a "higher order," this is reflected in increased capacity.

The BRT systems with the lowest capacity levels are typically those with on-street operations, less substantial stations and standard size vehicles, such as Honolulu's BRT lines and the AC Transit San Pablo Rapid; these systems have maximum capacities from 200 to 400 passengers per direction per hour (ppdph). Systems that can accommodate 600 to 850 passengers per direction per hour typically feature one element of a higher order. For example, the Sydney Liverpool-Parramatta T-Way and North-West T-Way - Blacktown-Parklea (850 ppdph) lines have off-street busways but still use standard vehicles. By contrast, the Albuquerque Rapid operates on-street with enhanced shelters but uses articulated vehicles. The Las Vegas MAX uses articulated vehicles but operates in mixed traffic lanes for a portion of its route and uses relatively low-capacity shelters. Most systems in this range also offer station passing or multiple-vehicle platform length.

Four systems reported person capacities between 1,000 and 1,260: Eindhoven, Sydney North-West T-Way Parramatta-Rouse Hill line, and Boston's Silver Line Washington Street corridor. Of these, five operate primarily in exclusive busways, most located off-street. They also typically have higher capacity stations, and about half use articulated vehicles. The Ottawa and Sydney systems also allow passing at stations.

The four systems that reported person capacities between 2,400 and 5,000 are the BRT systems in Adelaide, Beijing, Guayaquil, and Pereira. All of these systems operate on off-street busways with articulated vehicles. Beijing, Guayaquil, and Pereira all use level boarding.

The top systems are Kunming's BRT network, Ottowa Busway (when counting the 95, 96, and 97 lanes and other routes), Brisbane's South East Busway, and Bogotá's Transmilenio. It should be noted that these are all BRT networks or services that accommodate multiple lines, so their capacity is much higher than a single BRT line. All operate off-street with very substantial stations and extremely high frequencies. Although the South East Busway uses standard vehicles, its stations can accommodate up to five vehicles, and some services run as frequently as every 16 seconds. This system has a total capacity of 15,000. Bogotá's Transmilenio is an order of magnitude higher than the other systems in this report, with a maximum capacity of 45,000 passengers per hour. As noted earlier, this easily matches rail system capacities. To achieve this, Bogotá uses off-street busways, articulated vehicles, spacious stations with passing capability and level boarding, and very high frequency.

The ITS elements noted in Exhibit 3-25—signal priority, intelligent vehicle systems, and operating management systems—likely contribute to overall capacity but do not obviously correlate with the higher capacity systems.

In general, the highest capacity systems can be found in Latin America, Australia, and China, which typically deploy integrated networks of BRT lines designed to meet either very high existing transit demand or, in the case of Brisbane, meet regional goals for increasing transit mode share. The mid-capacity systems are typically the European and Canadian systems, while most, but not all, of the lower-capacity systems are in the U.S. In many cases the operated capacity is low because corridor transit demand is low.

Systems should be designed to meet current and projected capacity needs, so a low capacity BRT can be a high-performing service, depending on the city's transit needs. It would be valuable to assess whether the BRT systems in Exhibit 3-25 are operating at or near maximum capacities to determine whether the person capacity is appropriate for the city's current needs and can accommodate future growth. Unfortunately, the performance data does not reveal this information. There are a few examples of capacity issues described in the System Performance Profiles section.

Exhibit 3-25: BRT Elements by System and Person Capacity

City, State / Province / Country	Albuquerque	Boston Silver Line		
BRT Line / System	Rapid Ride	Washington St	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Running Way (miles)				
On Street Mixed Lanes	13.1	0.2	3.5	1.2
On Street Exclusive Bus Lanes	0.7	2.2		
Off Street Mixed Lanes		0.0		
Off Street Reserved Lanes		0.0		
At-Grade Transitway		0.0		
Grade-Separated Transitway		-	1.0	1.0
Queue Jumpers				
Type	Enhanced Shelter	No Shelter, Basic Shelter, Enhanced Shelter & Transit Center	No Shelter, Underground Station & Transit Center	No Shelter, Underground Station & Transit Center
Curb Design	Standard Curb	Standard Curb	Standard Curb	Standard Curb
Platform Layout (No. of Vehicles Accommodated)	1	1	1 above ground; multiple w/ underground stations	1 above ground; multiple w/ underground stations
Passing Capability	-	-		
Vehicles				
Configuration	Articulated	Stylized Articulated	Articulated	Articulated
Length	60 ft	60 ft	60 ft	60 ft
ITS				
Transit Vehicle Prioritization	TSP	TSP - Green Extension, Red Truncation	No	No
Intelligent Vehicle Systems	None	None	None	none
Automated Scheduling and Dispatch		None	CAD	CAD
Vehicle Component Monitoring System		AVM		
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	11	4	10	10
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)	600	1,264	318	
Operated Maximum Vehicles Per Peak Hour (BRT Service)	10	9	6	
Operated Vehicles Per Peak Hour (Non-BRT Service)	103	0		
Total Ridership by Route				SL2 and SL3
Average Weekday Boardings in Corridor after BRT	12,430	14,102	9,338	7,434

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Chicago*			Cleveland	Eugene
BRT Line / System	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine	EmX
Running Way (miles)					
On Street Mixed Lanes	18.3	9.0	9.4	2.7	1.4
On Street Exclusive Bus Lanes				4.4	2.6
Off Street Mixed Lanes					
Off Street Reserved Lanes					
At-Grade Transitway					
Grade-Separated Transitway					
Queue Jumpers					Queue jump
Station					
Type	No Shelter	No Shelter	No Shelter	Enhanced Shelter	Enhanced Shelter, Station Building
Curb Design	Standard Curb	Standard Curb	Standard Curb	Near Level	Raised platform
Platform Layout (No. of Vehicles Accommodated)	1	1	1	1 40' + 1 60'	1
Passing Capability				No	No
Vehicles					
Configuration				Stylized articulated	Stylized articulated
Length	45-ft	45-ft	45-ft	60 ft	60 ft
ITS					
Transit Vehicle Prioritization				TSP	TSP
Intelligent Vehicle Systems				mechanical guidance	Visual guidance
Automated Scheduling and Dispatch					CAD
Vehicle Component Monitoring System					
Service Plan					
Frequency of Service in Peak Hours (Headway in Minutes)	9	12	11	5	10
Capacity					
Maximum Critical Link Throughput (persons per hour per direction)					
Operated Maximum Vehicles Per Peak Hour (BRT Service)	6.5	5	5.5		
Operated Vehicles Per Peak Hour (Non-BRT Service)					
Total Ridership by Route					
Average Weekday Boardings in Corridor after BRT					

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Honolulu			Kansas City	Las Vegas
BRT Line / System	City Express: A	City Express: B	Country Express: C	MAX - Main St	MAX
Running Way (miles)					
On Street Mixed Lanes	19.0	8.0	18.0	6.0	3.0
On Street Exclusive Bus Lanes				along certain segments, for certain times of day	4.5
Off Street Mixed Lanes			3.5		-
Off Street Reserved Lanes			17.5		-
At-Grade Transitway					-
Grade-Separated Transitway					-
Queue Jumpers					1 queue jumper
Station					
Type	Basic Shelter	Basic Shelter	Basic Shelter	Enhanced Shelter	Basic and Enhanced Shelter
Curb Design	Standard Curb	Standard Curb	Standard Curb	Raised Curb	Raised Curb
Platform Layout (No. of Vehicles Accommodated)	1	1	1	1	1
Passing Capability					-
Vehicles					
Configuration	Articulated	Standard	Articulated	Stylized Standard	Stylized Articulated
Length	60 ft	40 ft	60 ft	40 ft	60 ft
ITS					
Transit Vehicle Prioritization				TSP	TSP
Intelligent Vehicle Systems					Optical Docking (not used)
Automated Scheduling and Dispatch					CAD/AVL
Vehicle Component Monitoring System					X
Service Plan					
Frequency of Service in Peak Hours (Headway in Minutes)	15	15	30	9	12
Capacity					
Maximum Critical Link Throughput (persons per hour per direction)	400	260	200		600
Operated Maximum Vehicles Per Peak Hour (BRT Service)	8	8	4		6
Operated Vehicles Per Peak Hour (Non-BRT Service)					4
Total Ridership by Route					
Average Weekday Boardings in Corridor after BRT	40,000	33,000	12,000	4,450	10,000 (+38%)

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Los Angeles		Miami	Oakland
BRT Line / System	Orange Line	Metro Rapid (All Routes)	Busway	San Pablo Ave Rapid
			Partially updated	
Running Way (miles)				
On Street Mixed Lanes	1.0	229.5		14.0
On Street Exclusive Bus Lanes	-	-		
Off Street Mixed Lanes	0.0	0.0		
Off Street Reserved Lanes	0.0	0.0		
At-Grade Transitway	13.5	0.0	20.0	
Grade-Separated Transitway		-		
Queue Jumpers		Queue Jumpers		Queue jumpers
Station				
Type	Enhanced Shelter	No Shelter, Enhanced Shelter, Transit Center	Enhanced Shelter	Basic Shelter
Curb Design	8" Curb	Standard Curb	Standard Curb	Standard Curb
Platform Layout (No. of Vehicles Accommodated)	3 artics	1	2 to 3	1
Passing Capability	Passing Lane provided at each in-line station	-	Bus Pullouts	
Vehicles				
Configuration	Stylized Articulated	Stylized Standard and Articulated	Standard, Articulated, Minis	Stylized standard
Length	60 ft	40 / 45 / 60 ft	35 / 40 / 60 ft	40 ft
ITS				
Transit Vehicle Prioritization		TSP	No	TSP
Intelligent Vehicle Systems	None	None		
Automated Scheduling and Dispatch	x	x	CAD	Yes
Vehicle Component Monitoring System	None	None	Yes	
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	4	2-10	6	12
Capacity			2004 data	
Maximum Critical Link Throughput (persons per hour per direction)	x	x		385
Operated Maximum Vehicles Per Peak Hour (BRT Service)	28	324	4	5
Operated Vehicles Per Peak Hour (Non-BRT Service)	1800	1800		
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	62,597	464,600 for all corridors	23000 (179% increase since pre-busway)	6,000

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Orlando*	Phoenix			
BRT Line / System	LYMMO	RAPID - I-10 East	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17
Running Way (miles)					
On Street Mixed Lanes		6.5	4.8	12.3	8.0
On Street Exclusive Bus Lanes	-				
Off Street Mixed Lanes					
Off Street Reserved Lanes	-	14.0	8.0	10.3	11.5
At-Grade Transitway	3.0	-	-	-	-
Grade-Separated Transitway					
Queue Jumpers					
Station					
Type	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter
Curb Design	Standard Curb	standard curb	standard curb	standard curb	standard curb
Platform Layout (No. of Vehicles Accommodated)	2	1	1	1	1
Passing Capability	-	bus pullouts	bus pullouts	bus pullouts	bus pullouts
Vehicles					
Configuration	Stylized standard	Specialized composite bus	Specialized composite bus	Specialized composite bus	Specialized composite bus
Length	40-ft	45-ft	45-ft	45-ft	45-ft
ITS					
Transit Vehicle Prioritization	TSP	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection	TSP at 1 intersection
Intelligent Vehicle Systems	Collision warning, lane assist, precision docking	Collision Warning	Collision Warning	Collision Warning	Collision Warning
Automated Scheduling and Dispatch	-	Yes	Yes	Yes	Yes
Vehicle Component Monitoring System	-	-	-	-	-
Service Plan					
Frequency of Service in Peak Hours (Headway in Minutes)	5	10	10	10	10
Capacity					
Maximum Critical Link Throughput (persons per hour per direction)		63/bus	63/bus	63/bus	63/bus
Operated Maximum Vehicles Per Peak Hour (BRT Service)	12				
Operated Vehicles Per Peak Hour (Non-BRT Service)					
Total Ridership by Route					
Average Weekday Boardings in Corridor after BRT	Average boardings per trip increased by 33% one year after opening	607; 30% increase	435; 30% increase	533; 30% increase	797; 30% increase

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Pittsburgh*			Sacramento
BRT Line / System	East Busway	South Busway	West Busway	EBus - Stockton
Running Way (miles)				
On Street Mixed Lanes				8.0
On Street Exclusive Bus Lanes				0.0
Off Street Mixed Lanes	0.4	-	0.4	0.0
Off Street Reserved Lanes	-	-	-	0.0
At-Grade Transitway			4.6	0.0
Grade-Separated Transitway	8.7	4.3		None
Queue Jumpers				1 queue jumper
Station				
Type	Enhanced Shelter	Enhanced Shelter	Enhanced Shelter	No Shelter, Basic Shelter, Transit Center
Curb Design	Raised Curb	Raised Curb	Raised Curb	
Platform Layout (No. of Vehicles Accommodated)				
Passing Capability	passing allowed	passing allowed	passing allowed	None
Vehicles				
Configuration	Standard & Articulated	Standard & Articulated	Standard & Articulated	
Length	40 ft and 60 ft	40 ft and 60 ft	40 ft and 60 ft	40 ft
ITS				
Transit Vehicle Prioritization			Signal Priority (magnetic loop sensors)	TSP - Green Ext
Intelligent Vehicle Systems	Collision Warning	Collision Warning	Collision Warning	None
Automated Scheduling and Dispatch	-	-	-	None
Vehicle Component Monitoring System	-	-	-	None
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	0.58		1.33	15 min
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)				
Operated Maximum Vehicles Per Peak Hour (BRT Service)	104		45	6
Operated Vehicles Per Peak Hour (Non-BRT Service)				190 buses
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	30,000 daily riders	13,000 daily riders	8,700 daily riders	1,750

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	San Jose	Halifax	Ottawa	
BRT Line / System	Rapid 522	MetroLink	95	96
Running Way (miles)				
On Street Mixed Lanes	25.0	12.1	2.1	2.1
On Street Exclusive Bus Lanes	0.0	0.5		
Off Street Mixed Lanes	0.0	10.6	3.2	13.1
Off Street Reserved Lanes	0.0	-	8.7	3.8
At-Grade Transitway	0.0	-	12.0	8.2
Grade-Separated Transitway	-	-		
Queue Jumpers	Queue Jumpers			
Station				
Type	No Shelter, Basic Shelter and Enhanced Shelter; Transit Center	Basic Shelter, Station Enclosures	Station Enclosures and Buildings	Station Enclosures and Buildings
Curb Design	Standard Curb	Standard Curb	Standard Curb	Standard Curb
Platform Layout (No. of Vehicles Accommodated)	2	2		
Passing Capability	-	None	Bus Pullouts	Bus Pullouts
Vehicles				
Configuration	Stylized Standard and Articulated	Stylized Standard	Articulated	Standard
Length	40 / 60 ft	40 ft	60 ft	40 ft
ITS				
Transit Vehicle Prioritization	TSP - Green Extension, Red Truncation	TSP	TSP	TSP
Intelligent Vehicle Systems	None	None	None	None
Automated Scheduling and Dispatch	Trapeze	None	Yes	Yes
Vehicle Component Monitoring System	None	None	Under development	Under development
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	15	10	3-4	3-6
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)	774 (including local route)	67 passengers / hour	2,400	1,020
Operated Maximum Vehicles Per Peak Hour (BRT Service)	4	x	46	16
Operated Vehicles Per Peak Hour (Non-BRT Service)	5	x	832 for system	832 for system
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	21,300 (+ 18%)	7,266	60,358	10,893

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Ottawa	York	
BRT Line / System	97	VIVA Blue	VIVA Purple
Running Way (miles)			
On Street Mixed Lanes	2.1	20.3	17.1
On Street Exclusive Bus Lanes			
Off Street Mixed Lanes	5.2		
Off Street Reserved Lanes	1.2		
At-Grade Transitway	9.8		
Grade-Separated Transitway			
Queue Jumpers		Bus-Only Lanes at some intersections	Bus-Only Lanes at some intersections
Station			
Type	Station Enclosures and Buildings	Basic and Enhanced Shelter	Basic and Enhanced Shelter
Curb Design	Standard Curb	Standard Curb	Standard Curb
Platform Layout (No. of Vehicles Accommodated)		1	1
Passing Capability	Bus Pullouts	Bus Pullouts	Bus Pullouts
Vehicles			
Configuration	Articulated	Articulated	Standard
Length	60 ft	60	40 ft
ITS			
Transit Vehicle Prioritization	TSP	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction	Limited to buses that are behind schedule with a max of one bus per intersection per 2.5 minutes in any direction
Intelligent Vehicle Systems	None	None	None
Automated Scheduling and Dispatch	Yes	Yes	Yes
Vehicle Component Monitoring System	Under development	Oil temp, Oil pressure, Engine temp reported to control centre	Oil temp, Oil pressure, Engine temp reported to control centre
Service Plan			
Frequency of Service in Peak Hours (Headway in Minutes)	12	5	10
Capacity		Systemwide	Systemwide
Maximum Critical Link Throughput (persons per hour per direction)	1,000		
Operated Maximum Vehicles Per Peak Hour (BRT Service)	19	70	70
Operated Vehicles Per Peak Hour (Non-BRT Service)	832 for system	217 (excludes TTC contract lines)	217 (excludes TTC contract lines)
Total Ridership by Route			
Average Weekday Boardings in Corridor after BRT	26,488	28,000	7,300

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Bogota	Guayaquil	Pereira	Amsterdam
BRT Line / System	Transmilenio	Metrovia	Megabus	Zuidtangent
Running Way (miles)				
On Street Mixed Lanes	-	-	-	1.9
On Street Exclusive Bus Lanes	-	-	-	6.2
Off Street Mixed Lanes	-	-	-	2.5
Off Street Reserved Lanes	-	-	-	-
At-Grade Transitway	52.0	10.0	17.0	14.9
Grade-Separated Transitway				
Queue Jumpers	-	-	-	Queue Jumper
Station				
Type	Station	Station	Station	
Curb Design	Level Platform	Level Platform	Level Platform	Level platform
Platform Layout (No. of Vehicles Accommodated)	2 to 5	x	1 to 2	-
Passing Capability	Bus Pullouts at many stations. Some lines more than 2 lanes	No Passing	No Passing	
Vehicles				
Configuration	Stylized Articulated	Stylized Standard & Articulated	Stylized Articulated	Articulated
Length	18 m	x	18 m	18m
ITS				
Transit Vehicle Prioritization	x	x	x	RTSP
Intelligent Vehicle Systems	none	None	none	Only for Docking, Mechanical
Automated Scheduling and Dispatch	x	x	x	
Vehicle Component Monitoring System	x	x	x	
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	1 - 3	4 - 6	3 - 5	7.5 - 8
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)	45,000	5,000	5,000	
Operated Maximum Vehicles Per Peak Hour (BRT Service)	x	x	x	
Operated Vehicles Per Peak Hour (Non-BRT Service)	x	x	x	
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	1.26 million	>100,000	>100,000	27, 000-28,500

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Caen	Edinburgh	Eindhoven	Leeds
BRT Line / System	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus
Running Way (miles)				
On Street Mixed Lanes		1.9	2.2	-
On Street Exclusive Bus Lanes	9.2	2.2		3.8
Off Street Mixed Lanes		-	-	-
Off Street Reserved Lanes		-	-	-
At-Grade Transitway	0.1	0.9	7.2	2.2
Grade-Separated Transitway				
Queue Jumpers				
Station				
Type	Enhanced Shelters, Stations, Transit Centers			
Curb Design	Level platform	Level platform	Level platform	Level platform, Raised Curb
Platform Layout (No. of Vehicles Accommodated)				
Passing Capability				No Passing in guideway segments
Vehicles				
Configuration	Bi-Articulated	Standard single and double deck	Articulated, Bi-Articulated	Standard
Length	24.5m	11.4m(double deck), 12m single deck	18m(11), 24m (1)	
ITS				
Transit Vehicle Prioritization	Signal Priority- Automatic	TSP	TSP	Signal Priority in downtown areas
Intelligent Vehicle Systems	Mechanical- Central Guidance Rail	Mechanical	Electromagnetic docking (not in use)	Mechanical
Automated Scheduling and Dispatch		Yes		
Vehicle Component Monitoring System				
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	3-6 (where routes overlap)	3	8	2-8
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)			1,000	
Operated Maximum Vehicles Per Peak Hour (BRT Service)				
Operated Vehicles Per Peak Hour (Non-BRT Service)				
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	45,000	Route has second highest passenger volumes in Lothian Bus network	28,500	50% ridership growth in first 2.5 years

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	London	Rouen	Utrecht	Adelaide
BRT Line / System	Crawley	TEOR	Busway	North East Busway
Running Way (miles)				
On Street Mixed Lanes	11.2	8.7	3.5	
On Street Exclusive Bus Lanes	3.7	-	2.0	
Off Street Mixed Lanes	-	-	-	
Off Street Reserved Lanes	-	-	-	
At-Grade Transitway	0.9	14.9	4.8	
Grade-Separated Transitway				7.46
Queue Jumpers	-			
Station				
Type				Transit Centers
Curb Design	Standard Curb	Level Platform	Level platform	Standard Curb
Platform Layout (No. of Vehicles Accommodated)				Two stations allow 3 buses. One allows 4 buses.
Passing Capability				Passing at Interchanges. Busway is single 'track'
Vehicles				
Configuration	Standard	Articulated	Bi-Articulated	Standard Articulated = 60 Standard Rigid = 80
Length	11	17.9m(38), 18m(28)	25m	Merc Rigid 37.1ft/11.3m Merc Artic 57.4ft/17.5m Scania Rigid 38.7ft/11.8m
ITS				
Transit Vehicle Prioritization		Signal Priority- Automatic and Manual	Signal Priority- Automatic	Passive Priority (No active)
Intelligent Vehicle Systems	Mechanical	Optical	-	Mechanical Guide Rollers on Front Axle
Automated Scheduling and Dispatch				X
Vehicle Component Monitoring System				X
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	10	3	2-4	1.1
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)				4,500
Operated Maximum Vehicles Per Peak Hour (BRT Service)				130
Operated Vehicles Per Peak Hour (Non-BRT Service)				-
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	10,000	32,000	33,500 with partial operation of new line	28,000

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Brisbane		Sydney	
BRT Line / System	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea
Running Way (miles)				
On Street Mixed Lanes				
On Street Exclusive Bus Lanes			6.0	0.3
Off Street Mixed Lanes				
Off Street Reserved Lanes				
At-Grade Transitway			13.0	4.4
Grade-Separated Transitway	10.3	1.7		
Queue Jumpers				
Station				
Type	Stations, Transit Centers	Stations, Transit Centers	Basic and Enhanced Shelter; Stations	Stations, Transit Centers
Curb Design	Standard Curb	Standard Curb	Standard Curb	Standard Curb
Platform Layout (No. of Vehicles Accommodated)	Standard 4; Max is 5	Standard 4; Max is 5	Standard is 2; Max is 6.	Standard is 2; 4 at termini
Passing Capability	Bus Pullouts at Stations	Bus Pullouts at Stations	Bus Pullouts at Stations	Bus Pullouts at Stations
Vehicles				
Configuration	Standard Rigid	Standard Rigid	Standard Rigid	Standard Rigid
Length	40.8ft/12.45 m		41ft/12.5m	41ft/12.5m
ITS				
Transit Vehicle Prioritization	-	-	Signal Pre-emption including green extension and early green	-
Intelligent Vehicle Systems	None	None	None	None
Automated Scheduling and Dispatch	X	X	X	X
Vehicle Component Monitoring System	X	X	X	X
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	16 sec headway at Buranda Station	4.6	10.0	8.6
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)	15,000	750	850	650
Operated Maximum Vehicles Per Peak Hour (BRT Service)	294	13	13/14	7
Operated Vehicles Per Peak Hour (Non-BRT Service)	-	-	0	-
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	93,000		7,200	

Exhibit 3-25: BRT Elements by System and Person Capacity (cont'd.)

City, State / Province / Country	Sydney	Beijing	Hangzhou	Kunming
BRT Line / System	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Line B1	Busway network
Running Way (miles)				
On Street Mixed Lanes				
On Street Exclusive Bus Lanes	1.9		6.2	
Off Street Mixed Lanes		2.2		
Off Street Reserved Lanes				24.9
At-Grade Transitway	8.7	8.1		
Grade-Separated Transitway				
Queue Jumpers				
Station				
Type	Basic and Enhanced Shelters, Transit Centers	Stations		
Curb Design	Standard Curb	Level Platform	Standard Curb	Standard Curb
Platform Layout (No. of Vehicles Accommodated)	Standard is 2; 4 at termini			60 m
Passing Capability	Bus Pullouts at Stations	Multiple Lanes	Multiple Lanes	None
Vehicles				
Configuration	Standard Rigid	Articulated	Articulated	Standard
Length	41ft/12.5m	18 m	18 m	9 - 12 m
ITS				
Transit Vehicle Prioritization	-	TSP	TSP	
Intelligent Vehicle Systems	None	None	None	None
Automated Scheduling and Dispatch	X			
Vehicle Component Monitoring System	X			
Service Plan				
Frequency of Service in Peak Hours (Headway in Minutes)	4.0		3 - 4 minutes	
Capacity				
Maximum Critical Link Throughput (persons per hour per direction)	1,100	4,500		8,000
Operated Maximum Vehicles Per Peak Hour (BRT Service)	15			
Operated Vehicles Per Peak Hour (Non-BRT Service)	-			
Total Ridership by Route				
Average Weekday Boardings in Corridor after BRT	2,800	85,000		10,000

ACCESSIBILITY

For transit, the term "accessibility" is often used to describe general availability of service to all transit users or proximity to points of access (stations and stops) of the transit system. This document describes accessibility in a more specific sense—the ability and ease with which individuals with disabilities can use the transit system. In addition to other enhancements to the performance of BRT systems, the implementation of many BRT elements can significantly improve the accessibility of transit for both the disabled and the general public. This section provides accessibility factors to consider when planning, implementing, and operating a BRT system. (Additional resource materials will be available in late 2008 from Easter Seals Project ACTION [ESPA], which is overseeing development of an Accessibility Design Guide for BRT Systems. The design guide will describe factors to consider and lessons learned by transit agencies that have already implemented accessible BRT systems. The resource materials will be available on-line at *www.projectaction.org*.

Description of Accessibility

In the context of transit, the term "accessibility" is used to describe how easily people with disabilities can use the transit system. Accessibility is measured both in terms of whether programs, facilities, and vehicles meet the regulatory requirements and guidelines, as well as the extent to which transit systems have been designed to meet the overall mobility needs of all customers, including people with disabilities and older adults.

There are at least three major ways that transit system elements (including BRT system elements) can affect accessibility:

- **Physical accessibility**—removing physical barriers and facilitating physical entry into stations and vehicles
- **Accessibility of information—**making information available to all passengers, especially those with vision and hearing impairments
- **Safety**—providing enhanced safety treatments and preventing susceptibility to hazards through warnings and other design treatments

It is important to remember that to the improved accessibility for individuals with disabilities also improves accessibility improvements for all passengers.

With these three types of accessibility in mind, there are several ways that accessibility can be measured. Primarily, it can be measured in terms of compliance with applicable regulations, standards, and design guidance. Other ways of measuring accessibility involve both qualitative ratings and quantitative measures that suggest the impact of improved accessibility.

In the United States, transportation programs, facilities, and vehicles must meet the regulatory requirements of the Americans With Disabilities Act (ADA), including applicable standards set forth in the ADA Accessibility Guidelines (ADAAG) as adopted by the U.S. DOT. The ADA regulations and the ADAAG describe minimum accessibility requirements for meeting programmatic, architectural, structural, and/or operational conditions intended to allow most people with disabilities to use facilities and services. Compliance with these regulations and guidelines, however, does not fully describe the level of accessibility provided. Higher levels of accessibility can be achieved with the implementation of certain design treatments and BRT elements. In some cases, transit systems are now adopting the notion of "universal design," which embraces the concept of a "barrier-free" environment to provide a more accessible and usable system for all passengers including people with disabilities, older adults, children, and people with luggage or baby strollers, as well as the general public.

Other measures of accessibility capture its complex nature, as compared to other more tangible BRT system performance measures such as travel time and capacity. Measuring accessibility may include qualitative ratings of the level of accessibility. The level of accessibility may also be eventually measured quantitatively by the level of response and use by people with disabilities, as well as the availability of accessible elements such as level boarding and streamlined securement systems. Other complex quantitative measures may indicate the level of opportunities and destinations able to be reached through a particular transit system. This measure, however, is most useful for local comparisons. As it is difficult to measure across an entire system, it would be difficult to develop a rating that can be compared among systems.

In summary, the following can be used as indicators for accessibility in a BRT system:

- Compliance with regulations and requirements (ADA and ADAAG accessibility requirements in the United States)
- Qualitative ratings of ease of system use by people with disabilities, older adults, children, adults with strollers, and adults with luggage

- BRT ridership trends (e.g., rates of use) for people with disabilities and older adults
- Opportunity to reach jobs, services, housing, recreation, shopping, and entertainment within a reasonable time frame and without being impeded by physical barriers when using the BRT system

The Effects of BRT Elements on Access to and Use of the BRT System

The following BRT elements are directly related to accessibility and use of the system and should be considered when developing and implementing service.

Running Way—Running Way Type
On-street running way types, whether exclusive or non-exclusive, are generally closer to land uses and require less walking and access time, and have fewer physical barriers.
Running Way—Running Way Guidance
All guidance systems can reduce the horizontal gap between vehicles and stations, facilitating boarding for all passengers, but especially for passengers who use wheelchairs or other mobility aids.
Stations—Station Location
On-street station locations, especially those where station platforms are adjacent to street curbs, tend to have easier access.
Stations—Basic Station Type
More complex station types—station enclosures, station buildings, and intermodal terminals or transit centers—tend to require additional design attention to ensure barrier-free access and ease of entry and transfers.
Stations—Passenger Amenities
Passenger information amenities such as maps and real-time information can incorporate accommodations for people with vision impairments (public address systems and audio information kiosks and vending machines) and people with hearing impairments (real-time variable message signs).
Stations Curb Design
Curb designs that minimize the vertical gap between station platform and vehicle floors—raised curb, level curb, and sloped curb—facilitate boarding for all groups. Level boarding treatments allow for people using wheelchairs to board without the need to deploy ramps, which could delay service.
Use of detectable warning strips at boarding and alighting demarcations is an effective limit setting measure and provides delineators of the station areas.
Stations—Platform Layout
Platform layouts with assigned and well signed berths create a system that it is easier to understand and navigate.
Stations—Station Access
Integration to the surrounding infrastructure with attention to accessible pedestrian linkages allow for barrier-free access to/from the station and between transit elements and modes.
Vehicles—Vehicle Configuration
While partial low-floor vehicle configurations comply with minimum access standards for passengers with disabilities, specialized BRT vehicles with low floors throughout the interior allow easier access for all passengers.
Vehicles—Passenger Circulation Enhancement
Improved passenger circulation, through alternative seat layout, additional door channels, and the ability to maneuver, facilitate boarding for people with disabilities.
Enhanced wheelchair securement systems provide a safer, more accessible environment while minimizing boarding delays.
Vehicles—Propulsion System
Propulsion systems that provide a gentler ride, such as those involving hybrid-electric or electric propulsion systems, increase customer's on-board safety and comfort.
Fare Collection—Fare Collection Process
Off-board fare collection systems tend to facilitate boarding for all passengers.
Fare Collection—Fare Media/Payment Options
Contactless fare payment media and options (e.g., smart cards, commercial debit/credit cards, and mobile phones) are easier to use and access for all groups.
ITS—Intelligent Vehicle Systems
Precision docking, one of the Intelligent Vehicle Systems, improves the interface between vehicle and station, by eliminating the horizontal gap and ensuring boarding and alighting without physical barriers.

ITS—Service Planning and Operations Management
Automated Vehicle Location systems enable the implementation of Automated Voice Annunciation (AVA) systems.
ITS—Passenger Information
Real-time passenger information tools, wherever implemented (pre-trip, en-route, in stations and terminals, and in-vehicle) must all be designed to be used and understood by all passengers. These are critical tools to convey the details for users of the BRT.
Service and Operations Plan—Route Structure
A simple route structure is easier to understand for everyone, removing a barrier to use due to lack of understanding of its operation.
Integrated or network structures may reduce the number of required transfers.

Performance of Existing Systems

Analysis of experience with BRT elements and accessibility is limited. There are research studies of specific elements and of specific cases.

Research Summary

Accessible vehicles and transit facility design are both required by the ADA and are important elements for ensuring that all passengers have access to the BRT system by minimizing physical and information barriers. According to the American Public Transportation Association (APTA) *2008 Public Transportation Fact Book*, as of 2006, approximately 95 percent of fixed route bus and trolley bus vehicles were accessible (typically either via ramp or lift), and 80 percent of Light Rail Transit (LRT) vehicles were accessible (typically via infrastructure elements such as level boarding or wayside lifts). Additionally, more than 85 percent of commuter rail and 99 percent of heavy rail vehicles were accessible in 2006. What is not quantified is the level of infrastructure accessibility that has been achieved with respect to facilities and environmental infrastructure.

To date, there have been few studies documenting whether and how BRT system elements have improved accessibility specifically for people with disabilities. Currently, studies and regulatory requirements are the best sources of information for this topic.

An Accessibility Design Guide for BRT Systems is under development through Easter Seals Project ACTION and is planned for publication in late 2008. It will be available on-line through ESPA at *www.projectaction.org*. This guide will identify accessibility issues common to BRT systems, effective and ineffective ways of addressing those issues, and examples of how the issue was addressed in BRT systems. ("Bus Rapid Transit and Accessibility in the U.S." [September 2005] presents a bibliography of resources related to BRT and accessibility and is available online at *http:\\projectaction.easterseals.com/site/DocServer/BRT_QandA.pdf?docID=15943*.

Research exploring accessibility issues has so far addressed three major issues:

- low-floor vehicles and level boarding
- wheelchair securement
- information for persons with vision impairments

Low Floor Vehicles and Level Boarding

Research about low floor vehicles (initially focused on light rail) suggests their value for accessibility. Low floor vehicles offer:

- accessible and comfortable transportation for all passengers, especially persons using wheelchairs or other mobility devices
- easier access for elderly who previously had difficulty boarding conventional transit
- reduced station dwell times (Booz Allen & Hamilton 1995)

Since 1991, low-floor buses have gained increased usage among transit agencies. The enactment of the ADA has been a major force in the growing interest of low-floor buses, though transit agencies say that the primary reason for choosing low-floor buses is to provide accessibility for all customers, regardless of ability.

Several transit agencies surveyed reported that their customers liked the ease of boarding and alighting on a low-floor bus. Customer satisfaction and acceptance surveys conducted by numerous transit agencies reported that, in general, the acceptance of low-floor buses was positive. Chicago Transit Authority customers reported that low-floor buses were preferred over high-floor buses in all issues of service quality. A total of 91 percent of Metropolitan Atlanta Rapid Transit Authority (MARTA) customers gave low-floor buses a good or excellent overall rating (King 1998).

With BRT, the concept of level boarding through a better interface between the vehicle and the station platform has gained greater focus. Level boarding enables a faster passenger flow, both on and off vehicles, leading to minimization of dwell times and a decrease in total journey time. With increased throughput, productivity increases, allowing fewer vehicles to serve the same or improved routes. (Various technologies and strategies to achieve level boarding, as well as the operational issues, legal implications, and technology advancements surrounding level boarding are presented in Kantor et al.)

Wheelchair Securement

Alternative wheelchair securement, especially rear-facing wheelchair securement, has been shown to offer faster boarding and alighting and reduced dwell times at stops. Furthermore, experience suggests acceptance by persons using wheelchairs of rear-facing securement. In Europe, rear-facing systems have existed for more than a decade, and those consumers who have used them say they appreciate being able to use public transit buses independently, without much assistance. On BC Transit buses in Vancouver, Canada, where both forward- and rear-facing options are available, operators report that the rear-facing positions are often occupied first, suggesting a user preference (Rutenberg et al. 2003).

Recent testing of specific rear-facing securement devices suggests the promise for both operations and better accessibility. A study sponsored by the Transportation Development Centre of Montreal tested a configuration of an open area along the side of the bus wall, with a load bearing headrest and backrest and an aisle facing support. Because there are no belts or hooks used, the rear-facing design concept provides a significant level of independence to all riders. Additionally, the design can accommodate mobility devices of almost any size or weight.

Advantages of this application of rear-facing position include:

For the wheelchair passenger:

- the independent use of public transit low-floor buses in a dignified way
- no damage to wheelchairs and scooters by attaching belts and hooks
- no physical, undignified contact with drivers
- no dirty or soiled belts in contact with clothes

For the transit operator:

- reduction of dwell time from three minutes to about one minute per passenger
- no driver involvement, which speed up operation and eliminates injuries and driver's downtime
- no maintenance and replacement costs for belts
- no hazards for other passengers from loose belts

Results of the extensive testing indicated that the rear-facing design was safe for passengers using wheelchairs and scooters, even under severe driving conditions, provided that the breaks of the wheelchairs or scooters were applied and that an anti-tipping system was in place (Rutenberg and Hemily 2007).

Information for Persons with Vision Impairments

Some information technologies (not specific to BRT) can assist with accessibility for persons with vision impairments. In the United States, between 6.6 and 9.7 million persons cannot read printed signs at a normal viewing distance. A demonstration project in San Francisco tested effectiveness of Talking Signs as a wayfinding technique for persons with vision impairments. With the technology, remote infrared signage directly orients vision-impaired persons to their goal location and provides constant updates as to their progress to that location by repeating a directionally-selective voice message that originates at the sign and is transmitted by infrared light to a hand-held device. The intensity and clarity of the message increases as the location is approached.

After four months of unsupervised use of the Talking Signs system in San Francisco, subjects participated in focus groups to provide feedback and evaluate the program. Participants reported increased independence and confidence and decreased stress when Talking Sign technology was available. Researchers reported that one participant remarked that "in Powell station he was 'truly equal' to sighted passengers" (Crandall et al. 2003).

System Performance Profiles

Metropolitan Area Express (MAX), Las Vegas

In Las Vegas, the Regional Transportation Commission of Southern Nevada (RTC) has seen its MAX BRT line reduce travel times by nearly half when compared to conventional fixed-route bus service operating in the same corridor. MAX has several features that enhance accessibility. MAX operates mostly in its own dedicated bus lane adjacent to regular traffic without a grade separation. Stations are designed for level boarding augmented by flip-out ramps, if needed to bridge the gap. Fare payment is made via ticket vending machines located on each platform, allowing the passengers to use all four doors to board and alight. Dedicated bicycle racks that do not share space with the wheelchair securement area permits easy on/off maneuvering for bicyclists as well as people using wheelchairs. Additional straps located in the securement areas also facilitate wheelchair securement for wheelchairs and scooters. RTC also is working closely with vehicle manufacturers to enhance passenger flow and to develop safe and comfortable rear facing wheelchair securements that are designed to minimize securement time. In addition, RTC has undertaken additional driver training to ensure that all drivers are current on wheelchair securement and has noted that some drivers are able to secure a wheelchair in about 90 seconds.

BRT Elements by System and Accessibility

Several BRT systems explicitly planned for accessibility from the beginning. One example is the RTC in Las Vegas; another is Lane Transit District in Eugene, Oregon. Planners of both systems worked extensively with the community to plan and implement systems that would be accessible for everyone.

All BRT systems are required to be accessible for people with disabilities. For most systems, this effort includes low-flow buses and flip out or retractable ramps to facilitate wheelchair boarding. This section outlines the implementation of BRT elements that affect accessibility by system.

Exhibit 3-26 summarizes the use of features directly related to accessibility and use of the system in 36 cities around the world. These BRT systems reflect the growing use of low-floor buses throughout transit operations, not just in BRT service. Almost all of the systems listed report using low-floor buses. The few in the U.S. that do not exclusively use low-floor BRT vehicles are those that operate standard fleet buses on their BRT routes instead of a dedicated BRT fleet. Since it is common for a transit agency fleet to include some older, high-floor buses that have not reached the end of their useful life, it is possible for the BRT to be served by some of these vehicles.

All of the European systems use low-floor buses, with several using guidance strategies to achieve fully level boarding. The three Latin American systems also offer level boarding. In the United States, Canada, and Australia, level boarding is still not common, and it is even less common for agencies to implement docking guidance systems. As a result, most BRT systems in the United States rely on ramps or lifts to facilitate boarding for passengers who use wheelchairs or other mobility aids. As already noted, the Las Vegas RTC incorporated several strategies to enhance accessibility for its MAX BRT line, including level boarding, the first in the United States to do so. Two recently-implemented U.S. BRT systems have incorporated level or near-level boarding: the Eugene EmX and the Cleveland HealthLine. The Los Angeles Orange Line and the Pittsburgh Busway built raised platforms designed to minimize the step up into the vehicles; the Orange Line combines this with a low-floor bus fleet.

It is also common for BRT systems in the United States to implement passenger information systems at stations and on vehicles. This feature is intended to improve accessibility for all passengers. It is not clear yet whether it is common for these systems to be used to implement information systems that are designed to enhance accessibility for persons with vision impairments. Only Boston, Phoenix and San Jose reported using stop announcements on their BRT vehicles.

There is little real-world data on the extent of rear-facing wheelchair securement in BRT systems. Some preliminary research does suggest that it is preferred by passengers. However, many of the BRT systems in Exhibit 3-26 do report using belts or tie-down devices, which research has indicated is considered less desirable by the passengers who use them. Of note, all of the Australian BRT systems indicate that they use rear-facing systems, and Oakland, which uses European-styled buses, also has a rear-facing system.

Exhibit 3-26: BRT Elements by System and Accessibility

City, State / Province / Country	Albuquerque	Boston Silver Line		
BRT Line / System	Rapid Ride	Washington St	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Running Way (mi)				
On-Street Running Ways	13.8	2.4	3.5	1.2
Off-Street Running Ways	0.0	0.0	1.0	1.0
Station				
Location	On-street	On-street	On- and off-street	On- and off-street
Type	Enhanced shelter	No shelter, basic shelter, enhanced shelter & transit center	No shelter, underground station & transit center	No shelter, underground station & transit center
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)	1	1	1 above ground; multiple w/ underground stations	1 above ground; multiple w/ underground stations
Access/Park-and-Ride Lots	2 lots	Pedestrian focus		90% arrive by public transit; 8% by walking
Vehicles				
Configuration	Articulated	Stylized articulated	Articulated	Articulated
Floor Height	Low	Low	Low	Low
Interior Features	Molded plastic with fabric inserts	Standard seats in 2+2 configuration	Luggage racks for airport line	
Wheelchair Loading		Low	Ramp	Ramp
Wheelchair Securement	Belts		Tie-down	Tie-down
Propulsion System and Fuel	Hybrid-electric, ULSD	ICE CNG	Dual-mode diesel & electric, ULSD	Dual-mode diesel & electric, ULSD
Fare Collection				
Fare Collection Process	Pay on-board	Pay on-board		
Fare Media and Payment Options	Cash & Paper only	Cash / Paper Transfers / Magnetic Stripe / Smart Cards	cash, paper ticket, smart card	cash, paper ticket, smart card
ITS				
Intelligent Vehicle Systems	None	None	None	none
Automatic Vehicle Location (AVL)	GPS	GPS	GPS, dead reckoning in tunnel	GPS, dead reckoning in tunnel
Passenger Information	At station / on vehicle, LED Nextbus signs	VMS at stations and in-vehicle	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements	LED signs with schedule info at stations; vehicles have public address and VMS with stop announcements
Service Plan				
Route Structure	Overlapping route	Replaced existing route	New service & replacing local service	New service & replacing local service

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Chicago*			Cleveland
BRT Line / System	Western Avenue Express	Irving Park Express	Garfield Express	HealthLine
Running Way (mi)				
On-Street Running Ways	18.3	9.0	9.4	7.1
Off-Street Running Ways	0.0	0.0	0.0	0.0
Station				
Location	On-street	On-street	On	On-street
Type	No shelter	No shelter	No shelter	Enhanced shelter
Curb Design	Standard curb	Standard curb	Standard curb	Near level
Platform Layout (# vehicles accommodated)	1	1	1	1 40' + 1 60'
Access/Park-and-Ride Lots	0 lots	0 lots	0 lots	
Vehicles				
Configuration				Stylized articulated
Floor Height	Low	Low	Low	Low
Interior Features				Wide aisles and doors
Wheelchair Loading				
Wheelchair Securement				
Propulsion System and Fuel				Hybrid diesel
Fare Collection				
Fare Collection Process	Pay on-board	Pay on-board		
Fare Media and Payment Options	Cash & Paper	Cash & Paper	Cash & Paper	
ITS				
Intelligent Vehicle Systems	None	None	None	mechanical guidance
Automatic Vehicle Location (AVL)				Yes
Passenger Information				Real time passenger info
Service Plan				
Route Structure				Replaced

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Eugene	Honolulu		
BRT Line / System	EmX	City Express: A	City Express: B	Country Express: C
Running Way (mi)				
On-Street Running Ways	4.0	19.0	8.0	18.0
Off-Street Running Ways	0.0	0.0	0.0	21.0
Station				
Location	On-street	On-street	On-street	On-street
Type	Enhanced shelter, station building	Basic shelter	Basic shelter	Basic shelter
Curb Design	Raised platform	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)	1	1	1	1
Access/Park-and-Ride Lots	Pedestrian focus; bike lockers and racks	0 lots	0 lots	0 lots
Vehicles				
Configuration	Stylized articulated	Articulated	Standard	Articulated
Floor Height	Low	Low	High	Low
Interior Features	Wide aisles and doors			
Wheelchair Loading	Low floor, ramp	Ramp	Lift	Ramp
Wheelchair Securement		-	-	
Propulsion System and Fuel	Hybrid diesel	Diesel / Hybrid-Electric	Diesel	Diesel / Hybrid-Electric
Fare Collection				
Fare Collection Process	None -- to be off board	Pay on-board		
Fare Media and Payment Options	N/A	Cash & Paper	Cash & Paper	Cash & Paper
ITS				
Intelligent Vehicle Systems	Visual guidance			
Automatic Vehicle Location (AVL)	GPS	GPS	GPS	GPS
Passenger Information	Vehicle, Web	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations	Traveler Information planned on vehicles, at several stations
Service Plan				
Route Structure	Replaced	Overlaps local route	Overlaps local route	Overlaps local route

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Kansas City	Las Vegas	Los Angeles	
BRT Line / System	MAX - Main St	MAX	Orange Line	Metro Rapid (All Routes)
Running Way (mi)				
On-Street Running Ways	6.0	7.5	1.0	229.5
Off-Street Running Ways	0.0	0.0	13.5	0.0
Station				
Location	On-street	On- and off-street	Off-street	On and Off
Type	Enhanced shelter	Basic and enhanced shelter	Enhanced shelter	No shelter, enhanced shelter, transit center
Curb Design	Raised curb	Raised curb	8" curb	Standard curb
Platform Layout (# vehicles accommodated)	1	1	3 artics	1
Access/Park-and-Ride Lots	Pedestrian focus	Pedestrian focus	Majority arrive by transit, walking or bike. Bike path & pedestrian walkway. 7 park-and-ride lots.	Pedestrian focus
Vehicles				
Configuration	Stylized standard	Stylized articulated	Stylized articulated	Stylized standard and articulated
Floor Height	Low	Low	Low floor (15")	Low floor (15")
Interior Features	Modern-looking interior, increased aisle width, increase hip-to-knee room, wider doors, wider windows	Modern auto-like interior, finished window glazing	USSC Aries cloth seats	
Wheelchair Loading	Low floor, ramp	ramp	Ramp (at front door only)	Ramp (at front door only)
Wheelchair Securement			Telescoping ARM	Telescoping ARM
Propulsion System and Fuel	ULSD	Diesel electric hybrid	ICE CNG	ICE CNG
Fare Collection				
Fare Collection Process	Pay on-board	Proof-of-payment		
Fare Media and Payment Options	Cash & Magnetic Stripe	Magnetic Stripe	Tickets from TVM and standard paper passes	Cash and Paper Passes
ITS				
Intelligent Vehicle Systems		Optical docking (not used)	None	None
Automatic Vehicle Location (AVL)	GPS	Orbital	GPS, loop detectors	GPS, loop detectors
Passenger Information	Real-time at all stations, trip planning	Station, telephone, internet, on-vehicle electronic displays	Nextbus VMS	Nextbus VMS at stations, telephone, internet
Service Plan				
Route Structure	Replaced local service	Overlaps local route	New line (parallel to several local routes, but off-street on new ROW)	Overlaid on local routes

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Miami	Oakland	Orlando*	Phoenix
BRT Line / System	Busway	San Pablo Ave Rapid	LYMMO	RAPID - I-10 East
Running Way (mi)				
On-Street Running Ways	0.0	14.0	0.0	6.5
Off-Street Running Ways	20.0	0.0	3.0	14.0
Station				
Location	Off-street	On-street	Off-street	On-street
Type	Enhanced shelter	Basic shelter	Enhanced shelter	Enhanced shelter
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)	3-Jan	1	2	1
Access/Park-and-Ride Lots	6 lots; bike path	Pedestrian focus	Pedestrian focus, 1 lot	Commuter service; 250-500 car lots
Vehicles				
Configuration	Standard, articulated, minis	Stylized standard	Stylized standard	Specialized composite bus
Floor Height		Low	Low	Low
Interior Features				High-back seating, forward facing, luggage racks, overhead lighting, reclining seats
Wheelchair Loading	Lifts	Ramps		
Wheelchair Securement		Rear-Facing Position		
Propulsion System and Fuel	Hybrid, CNG, diesel	Ultra-low-sulfur diesel	ICE CNG	LNG
Fare Collection				
Fare Collection Process	Pay on-board	Pay on-board		
Fare Media and Payment Options	Cash, paper swipe card		Free	Cash, magnetic swiping
ITS				
Intelligent Vehicle Systems			Collision warning, lane assist, precision docking	Collision warning
Automatic Vehicle Location (AVL)	AVL	GPS	AVL/Wi-Fi	Orbital
Passenger Information	Traveler information at stations and on vehicle	Real-time arrival at stations; traveler info on vehicle & via PDA	Traveler Information at stations and on vehicle; web-based	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info
Service Plan				
Route Structure				

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Phoenix			Pittsburgh*
BRT Line / System	RAPID - I-10 West	RAPID - SR-51	RAPID - I-17	East Busway
Running Way (mi)				
On-Street Running Ways	4.8	12.3	8.0	0.0
Off-Street Running Ways	8.0	10.3	11.5	9.1
Station				
Location	On-street	On-street	On-street	Off-street
Type	Enhanced shelter	Enhanced shelter	Enhanced shelter	Enhanced shelter
Curb Design	Standard curb	Standard curb	Standard curb	Raised curb
Platform Layout (# vehicles accommodated)	1	1	1	
Access/Park-and-Ride Lots	Commuter service; 250-500 car lots	Commuter service; 250-500 car lots	Commuter service; 250-500 car lots	16 lots
Vehicles				
Configuration	Specialized composite bus	Specialized composite bus	Specialized composite bus	Standard & articulated
Floor Height	Low	Low	Low	
Interior Features	High-back seating, forward facing, luggage racks, overhead lighting, reclining seats	High-back seating, forward facing, luggage racks, overhead lighting, reclining seats	High-back seating, forward facing, luggage racks, overhead lighting, reclining seats	Cushioned seats
Wheelchair Loading				
Wheelchair Securement				
Propulsion System and Fuel	LNG	LNG	LNG	Standard diesel with 5 CNG
Fare Collection				
Fare Collection Process	Pay on-board	Pay on-board		
Fare Media and Payment Options	Cash, magnetic swiping	Cash, magnetic swiping	Cash, magnetic swiping	Cash and paper only
ITS				
Intelligent Vehicle Systems	Collision warning	Collision warning	Collision warning	Collision warning
Automatic Vehicle Location (AVL)	Orbital	Orbital	Orbital	
Passenger Information	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.	Real-time arrival at stations; on-vehicle announcements; PDA and web-based info.	
Service Plan				
Route Structure				B

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Pittsburgh*		Sacramento	San Jose
BRT Line / System	South Busway	West Busway	EBus - Stockton	Rapid 522
Running Way (mi)				
On-Street Running Ways	0.0	0.0	8.0	25.0
Off-Street Running Ways	4.3	5.0	0.0	0.0
Station				
Location	Off-street	Off-street	On- and off-street	On- and off-street
Type	Enhanced shelter	Enhanced shelter	No shelter, basic shelter, transit center	No shelter, basic shelter and enhanced shelter; transit center
Curb Design	Raised curb	Raised curb		Standard curb
Platform Layout (# vehicles accommodated)				2
Access/Park-and-Ride Lots	12 lots	10 lots		3 with 281 spaces. 3 existing lots with 1300 spaces at commuter rail stations
Vehicles				
Configuration	Standard & articulated	Standard & articulated		Stylized standard and articulated
Floor Height			Low	Low (15")
Interior Features	Cushioned seats	Cushioned seats	Standard	Typical transit bus - front facing, upholstered seats
Wheelchair Loading			Kneeling, low-floor, ramp	Low-floor 15"
Wheelchair Securement			Forward facing	Forward-facing 4-point restraint
Propulsion System and Fuel	Standard diesel with 5 CNG	Standard diesel with 5 CNG	ICE CNG	ICE LSD
Fare Collection				
Fare Collection Process	Pay on-board	Pay on-board		
Fare Media and Payment Options	Cash and paper only	Cash and paper only	Cash and passes	Cash and paper passes, smart cards in development
ITS				
Intelligent Vehicle Systems	Collision warning	Collision warning	None	None
Automatic Vehicle Location (AVL)			None	GPS
Passenger Information			On vehicle	Automated next stop announcements. Real-Time info in development. Automated trip planning through website
Service Plan				
Route Structure			Replaced limited service route	Overlaps existing local route, headway (not schedule) based

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Halifax	Ottawa		
BRT Line / System	MetroLink	95	96	97
Running Way (mi)				
On-Street Running Ways	12.6	2.1	2.1	2.1
Off-Street Running Ways	10.6	23.8	25.1	16.3
Station				
Location	On- and off-street	On- and off-street	On- and off-street	On- and off-street
Type	Basic shelter, station enclosures	Station enclosures and buildings	Station Enclosures and Buildings	Station Enclosures and Buildings
Curb Design	Standard curb	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)	2			
Access/Park-and-Ride Lots	6 lots			
Vehicles				
Configuration	Stylized standard	Articulated	Standard	Articulated
Floor Height	Low	14.5 - 16"; 11.5" kneeling	14.5 - 16"; 11.5" kneeling	14.5 - 16"; 11.5" kneeling
Interior Features	Cloth seats, reclining with arm / foot rests	Cloth seats	Cloth seats	Cloth seats
Wheelchair Loading	Low-floor buses, kneeling buses, ramps	Low floor buses, kneeling buses, ramps	Low floor buses, kneeling buses, ramps	Low floor buses, kneeling buses, ramps
Wheelchair Securement	Belt	Belt	Belt	Belt
Propulsion System and Fuel	ICE Biodiesel	ICE Low-sulfur diesel	ICE Low-sulfur diesel	ICE Low-sulfur diesel
Fare Collection				
Fare Collection Process	Pay on-board	Proof-of-Payment		
Fare Media and Payment Options	Cash / tickets / passes	Cash / tickets / passes	Cash / tickets / passes	Cash / tickets / passes
ITS				
Intelligent Vehicle Systems	None	None	None	None
Automatic Vehicle Location (AVL)	AVL	GPS	GPS	GPS
Passenger Information	Real-time display, trip planning	Yes	Yes	Yes
Service Plan				
Route Structure	Overlapping route			

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	York		Bogotá	Guayaquil
BRT Line / System	VIVA Blue	VIVA Purple	Transmilenio	Metrovia
Running Way (mi)				
On-Street Running Ways	20.3	17.1	0.0	0.0
Off-Street Running Ways	0.0	0.0	52.0	10.0
Station				
Location	On- and off-street	On- and off-street	Off-street	Off-street
Type	Basic and enhanced shelter	Basic and enhanced shelter	Station	Station
Curb Design	Standard curb	Standard curb	Level platform	Level platform
Platform Layout (# vehicles accommodated)	1	1	2 to 5	
Access/Park-and-Ride Lots			No lots	No lots
Vehicles				
Configuration	Articulated	Standard	Stylized articulated	Stylized standard & articulated
Floor Height	Low	Low	0.9 m	
Interior Features	Cloth seats in spacious arrangement and tables for workspace at some rear seats. WiFi being deployed. Large windows. Bright, large in-vehicle display screens	Cloth seats in spacious arrangement and tables for workspace at some rear seats. WiFi being deployed. Large windows. Bright, large in-vehicle display screens	Molded plastic seats, front/rear and side facing	
Wheelchair Loading	Low floor buses, kneeling buses, ramps	Low floor buses, kneeling buses, ramps	Level boarding	Level boarding
Wheelchair Securement	Belt	Belt		
Propulsion System and Fuel	ICE Clean diesel	ICE Clean diesel	Diesel; CNG pilot project underway with 3 buses	
Fare Collection				
Fare Collection Process	Proof-of-Payment	Proof-of-Payment		
Fare Media and Payment Options	Paper tickets or passes	Paper tickets or passes	Smart cards	Cash, smart cards
ITS				
Intelligent Vehicle Systems	None	None	None	None
Automatic Vehicle Location (AVL)	AVL-equipped	AVL-equipped	Loop detectors, station sensors	On-board transponders
Passenger Information	VMS at stops and on-board	VMS at stops and on-board	Nextbus displays at stations	Nextbus displays at stations
Service Plan				
Route Structure	Overlays locals	Overlays locals	Replaced existing privately-operated routes	Replaced existing privately-operated routes

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Pereira	Amsterdam	Caen	Edinburgh
BRT Line / System	Megabus	Zuidtangent	Tram on Wheels	Fastlink
Running Way (mi)				
On-Street Running Ways	0.0	8.1	9.2	4.1
Off-Street Running Ways	17.0	17.4	0.1	0.9
Station				
Location	Off-street	On-street	On- and off-street	
Type	Station		Enhanced shelters, stations, transit centers	
Curb Design	Level platform	Level platform	Level platform	Level platform
Platform Layout (# vehicles accommodated)	1 to 2			
Access/Park-and-Ride Lots	No lots			
Vehicles				
Configuration	Stylized articulated	Articulated	Bi-articulated	Standard single and double deck
Floor Height	0.9 m	Low	Low	Low
Interior Features	Molded plastic seats, front/rear and side facing		"Bistro" style semi-circle seating at rear	
Wheelchair Loading	Level boarding		Tilting low floor	Kneeling, low floor & ramp
Wheelchair Securement				rear facing
Propulsion System and Fuel	ICE diesel	Diesel	Dual Mode- Traction motor on-rail/ diesel engine off-rail	Diesel
Fare Collection				
Fare Collection Process	Barrier (verify at station entrances)	Pay on-board or proof-of-payment		
Fare Media and Payment Options	Smart cards	Paper (Strippenkart)	Smart cards, magnetic tickets	Cash coin (exact change) or smart card
ITS				
Intelligent Vehicle Systems	None	Only for docking, mechanical	Mechanical - central guidance rail	Mechanical
Automatic Vehicle Location (AVL)	On-board transponders			GPS
Passenger Information	Nextbus displays at stations	Real-time stop information, timetabled	Real-time at station/stop, online-journey planner and timetable	Real-time, at station/stop, SMS
Service Plan				
Route Structure	Replaced existing privately-operated routes	New city orbital BRT link with intermodal links	Two routes overlapping in core area providing high frequency in downtown and Y pattern coverage north/south of downtown	Single radial route linking periphery to downtown

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Eindhoven	Leeds	London	Rouen
BRT Line / System	Phileas - Western Corridor	Superbus	Crawley	TEOR
Running Way (mi)				
On-Street Running Ways	2.2	3.8	14.9	8.7
Off-Street Running Ways	7.2	2.2	0.9	14.9
Station				
Location			On-street	On-street
Type				
Curb Design	Level platform	Level platform, raised curb	Standard curb	Level platform
Platform Layout (# vehicles accommodated)				
Access/Park-and-Ride Lots		1 park-and-ride		1000 parking spaces
Vehicles				
Configuration	Articulated, bi-articulated	Standard	Standard	Articulated
Floor Height	Low	Low	Low	Low Floor
Interior Features				
Wheelchair Loading	Level boarding	Kneeling, low floor	Kneeling, low floor	Level boarding
Wheelchair Securement			1 wheelchair capacity	
Propulsion System and Fuel	Hybrid (LPG/Electric)	Diesel	Diesel	Diesel
Fare Collection				
Fare Collection Process	Proof-of-payment, pay on-board machine, no driver payment	Pay on-board		
Fare Media and Payment Options	Paper (Strippenkart)	Cash and paper only	Cash	Magnetic stripe
ITS				
Intelligent Vehicle Systems	Electromagnetic docking (not in use)	Mechanical	Mechanical	Optical
Automatic Vehicle Location (AVL)				
Passenger Information	Real-time stop information, timetabled	Real-time, at station/stop, SMS	Time tabled, at station/stop	Real-time stop information, timetabled
Service Plan				
Route Structure	Two radial routes overlapping in central area, linking downtown with periphery and airport	Two radial routes linking periphery to downtown	2 north-south overlapping routes. Links downtown to employment areas to north (Gatwick) and south	Three radial routes overlapping in central area, linking downtown with hospital, universities and peripheral areas

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Utrecht	Adelaide	Brisbane	
BRT Line / System	Busway	North East Busway	South East Busway	Inner Northern Busway
Running Way (mi)				
On-Street Running Ways	5.5	0.0	0.0	0.0
Off-Street Running Ways	4.8	7.5	10.3	1.7
Station				
Location	On-street	Off-street	Off-street	Off-street
Type		Transit centers	Stations, transit centers	Stations, transit centers
Curb Design	Level platform	Standard curb	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)		Two stations allow 3 buses, one allows 4 buses	Standard 4; max 5	Standard 4; max 5
Access/Park-and-Ride Lots		3 lots; 1,190 spaces	3 lots, 759 spaces	None designated
Vehicles				
Configuration	Bi-articulated	Standard articulated = 60 Standard rigid = 80	Standard rigid	Standard rigid
Floor Height	Low Floor	Merc - step high, Scania - step low	Mainly step low, some step high	Mainly step low, some step high
Interior Features		Luggage racks over wheel hubs		
Wheelchair Loading	Level boarding	Front door ramp	Front door ramp	
Wheelchair Securement		Rear facing no straps	Rear facing no straps	
Propulsion System and Fuel	Diesel	Diesel	Mix of diesel and CNG gas buses	Mix of diesel and CNG gas buses
Fare Collection				
Fare Collection Process	Proof-of-payment, pay on-board	Pay on-board (80% pre pay multi-rider ticket)	Pay on-board	Pay on-board
Fare Media and Payment Options	Paper (Strippenkart)	Cash & paper magnetic stripe	Cash & paper magnetic stripe	
ITS				
Intelligent Vehicle Systems		Mechanical Guide Rollers on Front Axle	None	None
Automatic Vehicle Location (AVL)			GPS	GPS
Passenger Information	Real-time stop information, timetabled	City Web Site has Trip Planning	Real time info at stations	Real time info at stations
Service Plan				
Route Structure	Three radial routes linking downtown to periphery	BRT route network replaced local routes	BRT network, with BRT lines overlaid on existing local routes	BRT route network replaced local routes

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Sydney			Beijing
BRT Line / System	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT
Running Way (mi)				
On-Street Running Ways	6.0	0.3	1.9	0.0
Off-Street Running Ways	13.0	4.4	8.7	10.3
Station				
Location	On- and off-street	On- and off-street	On- and off-street	Off-street
Type	Basic and enhanced shelters, stations	Stations, transit centers	Basic and enhanced shelters, transit centers	Stations
Curb Design	Standard curb	Standard curb	Standard curb	Level platform
Platform Layout (# vehicles accommodated)	Standard 2; Max 6	Standard 2; 4 at termini	Standard 2; 4 at termini	
Access/Park-and-Ride Lots	1 designated lot	None designated	2 designated lots	
Vehicles				
Configuration	Standard rigid	Standard rigid	Standard rigid	Articulated
Floor Height	Step low	Step high	Step mix low, step high	Low
Interior Features				
Wheelchair Loading	Front door low floor ramp	Mix - a few low floor ramp		Low-floor /lLevel platforms
Wheelchair Securement	Rear facing no straps	Rear facing no straps	Rear facing no straps	
Propulsion System and Fuel	Euro 3 diesel	Diesel	Diesel	
Fare Collection				
Fare Collection Process	Pay on-board	Pay on-board	Pay on-board	Pay attendants at station
Fare Media and Payment Options	Cash & paper magnetic stripe	Cash & paper magnetic stripe	Cash & paper magnetic stripe	Cash, smart cards
ITS				
Intelligent Vehicle Systems	None	None	None	None
Automatic Vehicle Location (AVL)	Loop Detectors			Yes
Passenger Information	Real time info at stations	Real Time info at terminus stations only	Real Time info at terminus stations only	Real-time at stations and on vehicles
Service Plan				
Route Structure	BRT network, with BRT lines overlaid on existing local routes	BRT network, with BRT lines overlaid on existing local routes	BRT network, with BRT lines overlaid on existing local routes	BRT network replacing existing routes in busiest corridors

Exhibit 3-26: BRT Elements by System and Accessibility (cont'd.)

City, State / Province / Country	Hangzhou	Kunming
BRT Line / System	Line B1	Busway network
Running Way (mi)		
On-Street Running Ways	6.2	0.0
Off-Street Running Ways	0.0	24.9
Station		
Location	On-street	
Type		
Curb Design	Standard curb	Standard curb
Platform Layout (# vehicles accommodated)		60 m
Access/Park-and-Ride Lots		
Vehicles		
Configuration	Articulated	Standard
Floor Height	Low	High
Interior Features		
Wheelchair Loading		
Wheelchair Securement		
Propulsion System and Fuel		Diesel
Fare Collection		
Fare Collection Process	Pay at station	Pay on-board
Fare Media and Payment Options	Cash, smart cards	Cash, IC cards
ITS		
Intelligent Vehicle Systems	None	None
Automatic Vehicle Location (AVL)	Yes	
Passenger Information	Real-time at stations and on vehicles	Currently being implemented
Service Plan		
Route Structure	BRT network replacing existing routes in busiest corridors	Center-lane BRT network for existing routes in busiest corridors

Chapter 3 related BRT system elements to various attributes of performance of BRT systems. In addition to affecting how the BRT system itself performs, BRT system elements also have positive benefits to the transit rider, on the transit system as a whole, and the communities in which BRT systems operate. This chapter elaborates on five key benefits of implementing BRT—three system benefits and two community benefits.

System Benefits

- ***Higher ridership***—the primary mission of transit service is to provide a useful service to passengers; an increase in the number of passengers is a good indicator that the service is attractive and appropriately designed.
- ***Cost effectiveness***—the effectiveness of a given project in achieving stated goals and objectives per unit investment.
- ***Operating efficiency***—suggests how well BRT system elements support effective deployment of resources in serving transit passengers.

Community Benefits

- ***Transit-supportive land development***—transit-oriented development promotes livability and accessibility of communities and the increased value of properties and communities surrounding transit investments.
- ***Environmental quality***—an indicator of regional quality of life, supporting the health and well-being of the public and the attractiveness and sustainability of the urban and natural environment.

The discussion for each benefit includes five major subsections:

- a description of the benefit and how it is generated
- a description of how the benefit is measured
- an exploration on how BRT system elements and performance characteristics support the benefit
- a discussion of other factors that affect how benefits are realized
- a summary of experience in demonstrating the benefit for implemented BRT systems

Other Benefits

Like all successful transit modes, bus rapid transit may also result in other system benefits. These benefits can be significant and wide-ranging. Such benefits include:

- ***Increased revenue***—Revenue can be generated from new riders, new ways of collecting fares, or new auxiliary revenue sources (e.g., advertising opportunities on passenger information).
- ***Reduced congestion***—The ability to attract riders from private automobiles can help reduce or limit the growth in congestion.
- ***Economic productivity***—Improvements to BRT system design can save time for existing BRT passengers, improve mobility for new BRT passengers, and reduce congestion on the road network, saving time for automobile users and freight carriers.
- ***Quality of life***—Providing mobility alternatives and improving transit-supportive development can improve the quality of life of a region; transit also supports community preservation.
- ***Improved economic opportunities***—Providing additional mobility choices can enhance the pool of employment opportunities a regional population can pursue and reduce costs associated with more expensive modes; retail establishments and other businesses benefit from increased sales and labor force availability.
- ***Job creation***—Transit investment has direct positive impacts on employment for the construction, planning, and design of the facilities.

BRT systems may promote and generate these benefits to the transportation system and the community similar to other successful transit and transportation systems. When characterizing and measuring these benefits, communities need to recognize that the extent of these benefits is very specific to the context of the corridor and the region in which BRT systems operate. Furthermore, many other factors contribute to the benefits as well, making the task of separating the extent of the impact of BRT complex.

HIGHER RIDERSHIP

Benefit of Higher Ridership

Attracting higher ridership is one of the primary goals of any rapid transit investment. The ability to attract riders reaffirms the attractiveness of the transit service and confers many benefits to a region, including reduced congestion, increased accessibility, and reduced pollution.

Definition of Higher Ridership

When considering impacts on ridership, it is important to note that BRT systems attract three types of trips:

- existing transit trips that are diverted to the new BRT system from other transit systems/services
- new or “induced” trips that were not made previously by transit or any other mode
- trips that were previously made by another, non-transit mode (drive alone, carpool, walk or bicycle)

BRT systems have been successful in attracting the three types of trips.

Measures of Higher Ridership

Several statistics are useful to report when assessing the increase in ridership from implementing BRT. The various measures reflect several factors. BRT routes operate in different environments (overlapping existing routes or providing new ones). Sometimes ridership on BRT routes can be separated; sometimes it should be considered in the context of a corridor that includes several routes (local and BRT routes). In cases where several BRT routes overlap on a unified exclusive guideway, it is often useful to report the ridership of all routes associated with the BRT system. Finally, survey assessments of how many riders are attracted to transit are useful in assessing the extent of mode shift.

Measures of ridership include the following:

- ***Ridership on new BRT routes***—usefully reported when BRT operates in a similar corridor, but with such distinct characteristics that BRT ridership is easily reported separately. Ridership on new BRT routes is often compared to ridership on existing routes (before implementation), when previous measurements are available and/or when previous routes have been replaced by BRT routes, and ridership on existing routes (after implementation), when other parallel (often local-serving) routes continue to operate after implementation of BRT.
- ***Total ridership after BRT implementation***—reports the total ridership in a corridor (including local and BRT routes) after implementation of BRT service. This is also compared to ridership on existing routes to provide information on market share of the BRT service and the extent of growth in ridership due to implementation of BRT.
- ***Change in ridership in the corridor***—calls out the percentage growth in ridership in the corridor due to implementation of BRT.
- ***Attractiveness to ridership with access to other modes***—reports the results of attitudinal surveys. Survey statistics often report the percentage of passengers after implementation who previously used other modes of transportation (driving, walking, or other modes such as taxis or shuttles) or who previously did not make the trip.

Effects of BRT Elements on Ridership

The ability of BRT service to attract higher ridership depends on how much comparative advantage BRT provides over other transit alternatives with respect to the key service attributes explored in Chapter 3. The impacts are discussed below.

Travel Time Savings

Improvement in travel time (through speed improvement, delay reduction, and increases in service frequency) is the most important determinant of attracting riders to transit. To the extent that BRT reduces travel time along an existing travel corridor, net ridership may increase as a result of four effects:

- Improved in-vehicle travel time will attract riders who opt for BRT instead of another mode of transportation (drive, bicycle or walk).
- Riders of other existing transit services may be attracted to the BRT service.
- Improved travel time may also induce some new passengers to take a trip.
- Improved travel time will save existing passengers time and possibly induce them to make more trips.

Reliability

Service reliability impacts the occurrence of unanticipated wait time or delays in travel time. Recent experience suggests that ridership response to BRT improvements is higher than would normally be expected due to travel time savings alone. Reliability may play as significant a role in attracting riders as travel time savings. Statistics on the impact of reliability on ridership are scarce due to measurement difficulties, although more data collected through the new generation of operations management tools may help to quantify the magnitude of this effect.

Identity and Image

To the extent that the unique attributes of BRT services can be packaged in a well-designed image and identity, BRT deployment can be perceived as an enhanced transit service that caters to a niche travel market. Differentiating BRT service from other transit service is also critical to providing information as to where to access transit (e.g., stations and stops) and routing.

Safety and Security

For specific groups of potential transit riders, safety and security considerations can override travel time savings as a factor in making the decision to take transit. BRT systems that can assure passengers of an experience free of hazards, crimes, and security threats make them feel less vulnerable and more confident in choosing to start and continue using transit.

Capacity

Capacity has an obvious direct effect on ridership because it determines the maximum number of riders that can be accommodated on a BRT service. Ideally, a transit agency will scale the BRT service appropriately for projected ridership, allowing for desired ridership increases. Certain BRT elements—particularly the running way and the vehicle—may limit the total system capacity. For example, a dedicated running way that operates at-grade will have a lower capacity than a grade-separated running way that can maximize the number and frequency of buses in service without being constrained by the need to accommodate other traffic crossing the busway.

Other Factors Affecting Ridership

Additional BRT system attributes that affect ridership include:

- ***Population size and characteristics***—Transit systems that serve a broader service area and higher densities of passengers (i.e., large central business districts and other major activity centers) are more prone to attract transit riders (e.g., households without automobiles, children, low-income groups); corridors that experience growth due to new development should experience corresponding growth in ridership.
- ***Attractiveness of other modes***—When other modes of travel are inexpensive or convenient (e.g., parking is relative easy and inexpensive, high-speed or uncongested highways are available), transit's advantage may not be significant; this comparison is especially relevant when the price or level of service of other modes is changing significantly (e.g., when fuel prices increase or decrease dramatically or when the frequency of other transit routes is adjusted due to BRT implementation).
- ***Linkages to other modes***—The ability to link with other modes of transportation (e.g., commuter rail, inter-city rail, or pedestrian and bicycle modes) may increase the attractiveness of transit.

BRT Elements by System and Ridership

Exhibit 4-1 summarizes the BRT elements and performance impacts that may affect ridership numbers for 36 cities around the world. It also includes ridership performance information where made available. Ridership measurements provided are:

- average weekday boardings in corridor before BRT
- average weekday boardings in corridor after BRT
- percentage increase in ridership
- percentage of ridership coming from private motorized modes

The data confirm the connection between ridership totals and the type of running way, vehicle, station elements deployed, and service frequency. The ridership figures also confirm that all types of BRT systems can attract ridership and that BRT can accommodate extremely high transit demand. Particularly noteworthy are the ridership figures for systems based on high-capacity dedicated ROW networks. Many Latin American BRT systems are designed this way, with networks of multi-lane dedicated busways, high-capacity stations, and very high frequencies. As a result, these systems have extremely high ridership: the Guayaquil and Pereira BRT systems have more than 100,000 weekday boardings, while Bogotá's Transmilenio reports 1.26 million daily boardings. These systems demonstrate that BRT can be designed to meet rail-like ridership levels, as does the Brisbane South East Busway, which reports 93,000 average weekday boardings.

The data also show that while BRTs operating in mixed traffic lanes typically have lower ridership, some do match or exceed ridership on BRTs in dedicated ROWs. For example, the 20-mile Blue Line on York's VIVA BRT, which operates in mixed traffic, has an average weekday boarding of 28,000, the same ridership as Adelaide's North East Busway.

The two Chinese BRT systems that reported data revealed widely different ridership: the Beijing Line 1 BRT has 85,000 weekday boardings, while the BRT line in Kunming has 10,000. The European BRTs tend to be high ridership systems, with most reporting average weekday boardings between 27,000 and 45,000. In the U.S., there is a broader range of ridership levels, from 1,750 for the Sacramento E-Bus to 28,000 on the Los Angeles Orange Line. Most U.S. BRT lines report between 5,000 and 15,000 average weekday boardings, and these systems feature varying combinations of high-capacity elements.

The data reveal a wide range of ridership increases among the 17 cities that provided this data point. About half of the BRT routes experienced increases between 5 and 35 percent; four reported increases between 36 and 75 percent; and six reported increases of more than 100 percent. It is difficult to compare these results, since some systems are reporting ridership numbers after years of operation, others only months. Overall, this data set shows no clear correlation between travel time or reliability and the level of ridership increase. For example, the Boston Silver Line Washington Street corridor experienced a 75 percent increase while decreasing corridor travel times by only 9 percent and having a reliability ratio of 1.5. By contrast, the Halifax Metrolink system reports a 33 percent improvement in travel time but increased ridership by only 19 percent.

In addition, it is difficult to conclude that any particular BRT element attracts more riders. Only running way priority demonstrated any level of correlation to ridership increases. Approximately half of the systems with increases of 43 percent or higher run on dedicated busways for at least a significant portion of their service, while most of the systems with the smallest ridership increases are those operating in mixed traffic, but one of the best-performing systems, the Silver Line Washington Street, does as well. No other element clearly aligns with a particular ridership improvement outcome. Overall, it is likely that riders are attracted to a number of factors that include travel time and reliability but also a positive brand identity and frequent service. Furthermore, outside factors, such as the availability and quality of transportation alternatives, play an important role in determining ridership.

The data also reveal that some BRT systems can divert trips from private car to transit. Fourteen systems reported the percentage of ridership coming from private motorized modes. The results were mixed, but generally good, with half reporting between 19 and 33 percent of their ridership coming from private vehicles. The highest performing systems were the Albuquerque Rapid Ride and the Adelaide North East Busway. As with ridership increases, the dataset does not reveal a clear link between any BRT element or performance indicator and mode shift.

System Performance Profiles

VIVA, York Region, Ontario

The VIVA BRT in Ontario's York Region, north of Toronto, presents an effective strategy to building BRT ridership. York Region Transit is implementing the VIVA BRT network in stages. In the first phase, called Quick Start, the agency implemented high-capacity vehicles, off-board fare collection, enhanced stations, transit signal priority, and an extensive branding and marketing campaign. The service runs entirely in mixed traffic roadways, since acquiring ROW and building dedicated running ways entail a long implementation process, as well as higher costs. The agency has indicated that it wanted to deploy the BRT network as quickly as possible to allow corridor ridership to build and help justify Phase II – construction of on-street dedicated running ways.

Ridership on Corridors (York Region Transit)

Year	Conventional	VIVA	Total (Year)
2004	5,300,035	not in service	5,300,035
2005	5,832,559	1,423,066	7,255,625
2006	4,225,187	7,134,982	11,360,169
2007	4,074,346	8,296,397	12,370,743

The ridership results above indicate the success of this strategy, as corridor ridership has increased significantly since the VIVA opened. They also reveal that ridership has shifted from the conventional bus service to the VIVA. Agency representatives have reported anecdotally that riders will let one of the regular fleet buses pass by to wait for a VIVA bus. Phase II is now under way, with the agency acquiring ROW needed for the on-street busways.

Exhibit 4-1: BRT Elements by System and Ridership

City, State / Province / Country	Albuquerque	Boston Silver Line		
BRT Line / System	Rapid Ride	Washington St	Waterfront SL1 - Airport	Waterfront SL2 - BMIP
Running Way (miles)				
Total Length of Route (miles)	13.8	2.4	4.5	2.2
On-Street Running Ways	13.8	2.4	3.5	1.2
On Street Mixed Lanes	13.1	0.2	3.5	1.2
On Street Exclusive Bus Lanes	0.7	2.2		
Off Street Mixed Lanes		0.0		
Off Street Reserved Lanes		0.0		
At-Grade Transitway		0.0		
Grade-Separated Transitway		-	1.0	1.0
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	15%	9%		
Travel Time: BRT vs. Local Bus in same corridor		9%		
Reliability: Ratio of Maximum to Minimum Running Time	1.2	1.5		--
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	600	1,264		
Ridership Results				SL2 and SL3
Average Weekday Boardings in Corridor before BRT	7,430	7,327	7,507	3,756
Average Weekday Boardings in Corridor after BRT	12,430	14,102	9,338	7,434
% Increase in Ridership	67%	92%	24%	98%
Percentage of ridership coming from private motorized modes	68%	2%	22.0%	8.0%

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Chicago*			Cleveland, OH
BRT Line / System	Western Avenue Express	Irving Park Express	Garfield Express	Health line- only running time
Running Way (miles)				
Total Length of Route (miles)	18.3	9.0	9.4	7.1
On-Street Running Ways	18.3	9.0	9.4	7.1
On Street Mixed Lanes	18.3	9.0	9.4	2.7
On Street Exclusive Bus Lanes				4.4
Off Street Mixed Lanes				
Off Street Reserved Lanes				
At-Grade Transitway				
Grade-Separated Transitway				
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After				26%
Travel Time: BRT vs. Local Bus in same corridor	15%	25%	20%	
Reliability: Ratio of Maximum to Minimum Running Time	1.3	1.2	1.4	
Capacity: Maximum Critical Link Throughput (persons per hour per direction)				
Ridership Results				
Average Weekday Boardings in Corridor before BRT				
Average Weekday Boardings in Corridor after BRT				
% Increase in Ridership		9% (2004)	14% (2004)	
Percentage of ridership coming from private motorized modes				

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Cleveland	Eugene	Honolulu	
BRT Line / System	HealthLine	EmX	City Express: A	City Express: B
Running Way (miles)				
Total Length of Route (miles)	7.1	4.0	19.0	8.0
On-Street Running Ways	7.1	4.0	19.0	8.0
On Street Mixed Lanes	2.7	1.4	19.0	8.0
On Street Exclusive Bus Lanes	4.4	2.6		
Off Street Mixed Lanes				
Off Street Reserved Lanes				
At-Grade Transitway				
Grade-Separated Transitway				
Queue Jumpers		Queue jump		
Performance Indicators				
Travel Time: Change in Corridor Before vs. After			-	-
Travel Time: BRT vs. Local Bus in same corridor			-	-27%
Reliability: Ratio of Maximum to Minimum Running Time	--	2.2	1.1	1.3
Capacity: Maximum Critical Link Throughput (persons per hour per direction)			400	260
Ridership Results				
Average Weekday Boardings in Corridor before BRT		2,667	40,000	38,000
Average Weekday Boardings in Corridor after BRT		6,200	40,000	33,000
% Increase in Ridership		132%	0%	-13%
Percentage of ridership coming from private motorized modes				

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Honolulu	Kansas City	Las Vegas	Los Angeles
BRT Line / System	Country Express: C	MAX - Main St	MAX	Orange Line
Running Way (miles)				
Total Length of Route (miles)	39.0	6.0	7.5	14.5
On-Street Running Ways	18.0	6.0	7.5	1.0
On Street Mixed Lanes	18.0	6.0	3.0	1.0
On Street Exclusive Bus Lanes		along certain segments, for certain times of day	4.5	-
Off Street Mixed Lanes	3.5		-	0.0
Off Street Reserved Lanes	17.5		-	0.0
At-Grade Transitway			-	13.5
Grade-Separated Transitway			-	
Queue Jumpers			1 queue jumper	
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	-			16%
Travel Time: BRT vs. Local Bus in same corridor	-27%	25%	25%	x
Reliability: Ratio of Maximum to Minimum Running Time	1.2	--	1.1	1.1
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	200		600	x
Ridership Results				
Average Weekday Boardings in Corridor before BRT	11,000	3,400	7,000	41,580
Average Weekday Boardings in Corridor after BRT	12,000	4,450	10,000	62,597
% Increase in Ridership	9%	31%	43%	51%
Percentage of ridership coming from private motorized modes			10%	x

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Los Angeles	Miami		Oakland
BRT Line / System	Metro Rapid (All Routes)	Busway	Busway Local	San Pablo Ave Rapid
Running Way (miles)				
Total Length of Route (miles)	229.5	20.0	8.0	14.0
On-Street Running Ways	229.5	0.0	0.0	14.0
On Street Mixed Lanes	229.5			14.0
On Street Exclusive Bus Lanes	-			
Off Street Mixed Lanes	0.0			
Off Street Reserved Lanes	0.0			
At-Grade Transitway	0.0	20.0	8.0	
Grade-Separated Transitway	-			
Queue Jumpers	Queue Jumpers			Queue jumpers
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	x	29% (2004)	35%	
Travel Time: BRT vs. Local Bus in same corridor	Overall avg. of 25% faster than local bus routes			17% reduction from limited -stop route
Reliability: Ratio of Maximum to Minimum Running Time	--	1.0 (2004)	1.0	1.2
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	x			385
Ridership Results				
Average Weekday Boardings in Corridor before BRT	388,400			
Average Weekday Boardings in Corridor after BRT	464,600	23,000		13,000
% Increase in Ridership	20%	179% since pre-busway		
Percentage of ridership coming from private motorized modes	33% (based on rider surveys)			19%

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Orlando*	Phoenix		
BRT Line / System	LYMMO	RAPID - I-10 East	RAPID - I-10 West	RAPID - SR-51
Running Way (miles)				
Total Length of Route (miles)	3.0	20.5	12.8	22.5
On-Street Running Ways	0.0	6.5	4.8	12.3
On Street Mixed Lanes		6.5	4.8	12.3
On Street Exclusive Bus Lanes	-			
Off Street Mixed Lanes				
Off Street Reserved Lanes	-	14.0	8.0	10.3
At-Grade Transitway	3.0	-	-	-
Grade-Separated Transitway				
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After				
Travel Time: BRT vs. Local Bus in same corridor	0%			
Reliability: Ratio of Maximum to Minimum Running Time	0.0	--	--	--
Capacity: Maximum Critical Link Throughput (persons per hour per direction)		63/bus	63/bus	63/bus
Ridership Results		2004 data	2004 data	2004 data
Average Weekday Boardings in Corridor before BRT				
Average Weekday Boardings in Corridor after BRT		607	435	533
% Increase in Ridership	33% one year after opening	30%	30%	30%
Percentage of ridership coming from private motorized modes				

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Phoenix	Pittsburgh*		
BRT Line / System	RAPID - I-17	East Busway	South Busway	West Busway
Running Way (miles)				
Total Length of Route (miles)	19.5	9.1	4.3	5.0
On-Street Running Ways	8.0	0.0	0.0	0.0
On Street Mixed Lanes	8.0			
On Street Exclusive Bus Lanes				
Off Street Mixed Lanes		0.4	-	0.4
Off Street Reserved Lanes	11.5	-	-	-
At-Grade Transitway	-			4.6
Grade-Separated Transitway		8.7	4.3	
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After		52%	55%	26%
Travel Time: BRT vs. Local Bus in same corridor				
Reliability: Ratio of Maximum to Minimum Running Time	--	1.1	1.0	1.2
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	63/bus			
Ridership Results	2004 data	2004 data	2004 data	2004 data
Average Weekday Boardings in Corridor before BRT				
Average Weekday Boardings in Corridor after BRT	797	30,000	13,000	8,700
% Increase in Ridership	30%			135%
Percentage of ridership coming from private motorized modes				

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Sacramento	San Jose	Halifax	Ottawa
BRT Line / System	EBus - Stockton	Rapid 522	MetroLink	95
Running Way (miles)				
Total Length of Route (miles)	8.0	25.0	23.2	25.9
On-Street Running Ways	8.0	25.0	12.6	2.1
On Street Mixed Lanes	8.0	25.0	12.1	2.1
On Street Exclusive Bus Lanes	0.0	0.0	0.5	
Off Street Mixed Lanes	0.0	0.0	10.6	3.2
Off Street Reserved Lanes	0.0	0.0	-	8.7
At-Grade Transitway	0.0	0.0	-	
Grade-Separated Transitway	None	-	-	12.0
Queue Jumpers	1 queue jumper	Queue Jumpers		
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	10%	x	33%	
Travel Time: BRT vs. Local Bus in same corridor	5%	20%	33%	
Reliability: Ratio of Maximum to Minimum Running Time	1.3	--	--	1.0
Capacity: Maximum Critical Link Throughput (persons per hour per direction)		774 (including local route)	67 passengers / hour	2,400
Ridership Results				
Average Weekday Boardings in Corridor before BRT	125	18,023	6,129	
Average Weekday Boardings in Corridor after BRT	1,750	21,300	7,266	60,358
% Increase in Ridership	1300%	18%	19%	
Percentage of ridership coming from private motorized modes	Not Available	x	23%	

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Ottawa		York	
BRT Line / System	96	97	VIVA Blue	VIVA Purple
Running Way (miles)				
Total Length of Route (miles)	27.2	18.4	20.3	17.1
On-Street Running Ways	2.1	2.1	20.3	17.1
On Street Mixed Lanes	2.1	2.1	20.3	17.1
On Street Exclusive Bus Lanes				
Off Street Mixed Lanes	13.1	5.2		
Off Street Reserved Lanes	3.8	1.2		
At-Grade Transitway				
Grade-Separated Transitway	8.2	9.8		
Queue Jumpers			Bus-Only Lanes at some intersections	Bus-Only Lanes at some intersections
Performance Indicators				
Travel Time: Change in Corridor Before vs. After				
Travel Time: BRT vs. Local Bus in same corridor				
Reliability: Ratio of Maximum to Minimum Running Time	1.0	1.1	1.4	1.4
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	1,020	1,000	-	-
Ridership Results				
Average Weekday Boardings in Corridor before BRT				
Average Weekday Boardings in Corridor after BRT	10,893	26,488	28,000	7,300
% Increase in Ridership				
Percentage of ridership coming from private motorized modes				

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Bogota	Guayaquil	Pereira	Amsterdam
BRT Line / System	Transmilenio	Metrovia	Megabus	Zuidtangent
Running Way (miles)				
Total Length of Route (miles)	52.0	10.0	17.0	25.5
On-Street Running Ways	0.0	0.0	0.0	8.1
On Street Mixed Lanes	-	-	-	1.9
On Street Exclusive Bus Lanes	-	-	-	6.2
Off Street Mixed Lanes	-	-	-	2.5
Off Street Reserved Lanes	-	-	-	-
At-Grade Transitway	52.0	10.0	17.0	14.9
Grade-Separated Transitway				
Queue Jumpers	-	-	-	Queue Jumper
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	x	x	x	
Travel Time: BRT vs. Local Bus in same corridor	x	x	x	
Reliability: Ratio of Maximum to Minimum Running Time	--	--	--	--
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	45,000	5,000	5,000	
Ridership Results				
Average Weekday Boardings in Corridor before BRT	x	x	x	
Average Weekday Boardings in Corridor after BRT	1.26 million	>100,000	>100,000	27, 000-28,500
% Increase in Ridership				
Percentage of ridership coming from private motorized modes	9%	x	x	

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Caen	Edinburgh	Eindhoven	Leeds
BRT Line / System	Tram on Wheels	Fastlink	Phileas - Western Corridor	Superbus
Running Way (miles)				
Total Length of Route (miles)	9.3	5.0	9.4	6.0
On-Street Running Ways	9.2	4.1	2.2	3.8
On Street Mixed Lanes		1.9	2.2	-
On Street Exclusive Bus Lanes	9.2	2.2		3.8
Off Street Mixed Lanes		-	-	-
Off Street Reserved Lanes		-	-	-
At-Grade Transitway	0.1	0.9	7.2	2.2
Grade-Separated Transitway				
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After		70% reduction in average PM journey time for guideway segment		3 minute saving outbound / up to 11 minute saving inbound
Travel Time: BRT vs. Local Bus in same corridor				
Reliability: Ratio of Maximum to Minimum Running Time	--	11.0	--	--
Capacity: Maximum Critical Link Throughput (persons per hour per direction)			1,000	
Ridership Results				
Average Weekday Boardings in Corridor before BRT				
Average Weekday Boardings in Corridor after BRT	45,000	Route has second highest passenger volumes in Lothian Bus network	28,500	
% Increase in Ridership				50% in first 2.5 years
Percentage of ridership coming from private motorized modes				10-20%

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	London	Rouen	Utrecht	Adelaide
BRT Line / System	Crawley	TEOR	Busway	North East Busway
Running Way (miles)				
Total Length of Route (miles)	15.8	23.6	10.3	7.5
On-Street Running Ways	14.9	8.7	5.5	0.0
On Street Mixed Lanes	11.2	8.7	3.5	
On Street Exclusive Bus Lanes	3.7	-	2.0	
Off Street Mixed Lanes	-	-	-	
Off Street Reserved Lanes	-	-	-	
At-Grade Transitway	0.9	14.9	4.8	
Grade-Separated Transitway				7.46
Queue Jumpers	-			
Performance Indicators				
Travel Time: Change in Corridor Before vs. After				-40% (Approx)
Travel Time: BRT vs. Local Bus in same corridor				-66%
Reliability: Ratio of Maximum to Minimum Running Time	--	--	--	1.3
Capacity: Maximum Critical Link Throughput (persons per hour per direction)				4,500
Ridership Results				
Average Weekday Boardings in Corridor before BRT	3,500			
Average Weekday Boardings in Corridor after BRT	10,000	32,000	33,500 with partial operation of new line	28,000
% Increase in Ridership	186%			
Percentage of ridership coming from private motorized modes	24%			40%

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Brisbane		Sydney	
BRT Line / System	South East Busway	Inner Northern Busway	Liverpool-Parramatta T-Way	North-West T-Way - Blacktown-Parklea
Running Way (miles)				
Total Length of Route (miles)	10.3	1.7	19.0	4.7
On-Street Running Ways	0.0	0.0	6.0	0.3
On Street Mixed Lanes				
On Street Exclusive Bus Lanes			6.0	0.3
Off Street Mixed Lanes				
Off Street Reserved Lanes				
At-Grade Transitway			13.0	4.4
Grade-Separated Transitway	10.3	1.7		
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	-65% in peak	0	-	-
Travel Time: BRT vs. Local Bus in same corridor	-	-	-	-
Reliability: Ratio of Maximum to Minimum Running Time	1.1	1.1	1.1	1.2
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	15,000	750	850	650
Ridership Results				
Average Weekday Boardings in Corridor before BRT			-	
Average Weekday Boardings in Corridor after BRT	93,000		7,200	
% Increase in Ridership				
Percentage of ridership coming from private motorized modes	26%		9%	

Exhibit 4-1: BRT Elements by System and Ridership (cont'd.)

City, State / Province / Country	Sydney	Beijing	Hangzhou	Kunming
BRT Line / System	North-West T-Way - Parramatta-Rouse Hill	Line 1 BRT	Line B1	Busway network
Running Way (miles)				
Total Length of Route (miles)	1.9	10.3	6.2	24.9
On-Street Running Ways	1.9	0.0	6.2	0.0
On Street Mixed Lanes				
On Street Exclusive Bus Lanes	1.9		6.2	
Off Street Mixed Lanes		2.2		
Off Street Reserved Lanes				24.9
At-Grade Transitway	8.7	8.1		
Grade-Separated Transitway				
Queue Jumpers				
Performance Indicators				
Travel Time: Change in Corridor Before vs. After	-	-38%		Speeds up 68%
Travel Time: BRT vs. Local Bus in same corridor	-			
Reliability: Ratio of Maximum to Minimum Running Time	1.0	--	--	--
Capacity: Maximum Critical Link Throughput (persons per hour per direction)	1,100	4,500		8,000
Ridership Results				
Average Weekday Boardings in Corridor before BRT				
Average Weekday Boardings in Corridor after BRT	2,800	85,000		10,000
% Increase in Ridership				
Percentage of ridership coming from private motorized modes				

CAPITAL COST EFFECTIVENESS

Benefit of Capital Cost Effectiveness

A primary advantage of BRT technology is that it can be adapted to meet the needs of a broad variety of operating environments while maintaining the ability to scale service to meet future ridership growth. The challenge in designing a new BRT system is to select a mixture of design and operational elements whose combined capital costs can be reasonably justified according to expected service output and ridership levels. In other words, the challenge is to "right size" the level and types of BRT capital investments to meet service quality and throughput requirements in a cost-effective manner.

Definition of Capital Cost Effectiveness

Capital cost effectiveness measures the capital cost to deploy a BRT system per service output such as per rider, per service-mile, or per user travel time savings. In general, more cost-effective investments are preferable, as they deliver more investment benefits per dollar invested. The objective of these measures is not, however, to identify the lowest-cost investment alternative. For transit investments, it is frequently the case that higher-cost alternatives are more cost-effective if they deliver sufficiently higher benefits, as compared to a lower-cost alternative. The objective of capital cost-effectiveness measures, then, is to help determine which combinations of BRT elements deliver the highest investment benefits (e.g., passenger throughput or travel time savings) per capital dollar invested. In practice, project capital costs can vary widely between alternative BRT investments, and, without the use of capital cost-effectiveness measures, it can be extremely daunting to assess which option represents the best solution to local transportation needs.

Measures of Capital Cost Effectiveness

Cost effectiveness can be defined as the cost per unit of service output. Evaluation of the capital cost effectiveness of BRT projects can be performed with respect to:

- ***user benefits***—passenger trips, passenger miles, cumulative travel time saved
- ***performance improvements***—average travel time savings, reliability improvements, safety and security improvements
- ***service outputs***—vehicle service miles (VSM), vehicle service hours (VSH)
- ***facility size***—miles of investment, vehicle fleet size

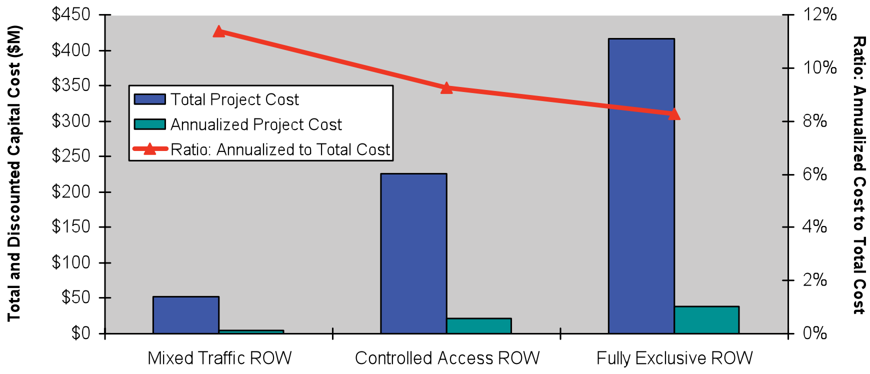
From the viewpoint of assessing the desirability of alternative BRT investments, some of these measures are more effective than others. Most notably, while measures of capital cost per service hour or per mile of alignment can help ensure that reasonable quantities of service or running way are purchased per dollar invested, they say nothing about whether the amounts invested are commensurate with the demand for those investments. For example, an investment alternative with a low capital cost per mile of alignment should not be considered a preferred alternative if it cannot serve supporting the expected passenger demand. Measures based on user benefits, including cost per rider, per passenger mile, or per hour of travel time savings, are not only useful in determining which investments provide good value per dollar invested but can also be used to help logically scale the investment to expected user demand.

Annualized Costs and Benefits

Regardless of the measure used, capital cost effectiveness, including both the cost value in the numerator and the output or benefits value in the denominator, should always be calculated on an "annualized" basis. The process of annualizing ensures that costs and benefits are compared over an equivalent and comparable time period (i.e., one year). It also ensures that the costs for all capital asset types (e.g., running way, vehicles, stations, etc.) are properly discounted to reflect differences in expected useful life. (Costs for individual investment elements should be annualized using the capital cost recovery factor x = [i*(1+i) n/((1+i)n-1)], where i is the discount rate and n is the expected useful life of the asset under consideration.)

Expanding on this last point, the process of annualizing costs has the effect of spreading the cost of project elements over many years, with the effect being most pronounced for assets with the longest lives. Hence, BRT projects with a relatively high investment in long-lived assets (e.g., tunnels and other structures) enjoy a higher level of discounting when costs are annualized, as compared to projects whose costs are more dominated by shorter-lived assets (e.g., vehicles). Note, however, that this effect is on a per-dollar invested basis. It should also be expected that projects with higher concentrations of longer-lived assets will also have higher total project costs. These relationships are presented in Exhibit 4-2, which compares the total capital and annualized costs of three different BRT investments with varying concentrations of investment in long-lived assets:

Exhibit 4-2: Per Dollar Invested, Annualized Costs Are Lower for BRT Investments with Higher Concentrations of Long-Lived Assets



1) a mixed traffic ROW alternative (which assumes minimal running way investment and simple transit stops; average asset useful life of 32 years), 2) a fully-exclusive ROW alternative (which assumes extensive running way investment and passenger stations with full amenities; average asset useful life of 52 years), and 3) an intermediate controlled-access alternative (average asset useful life of 48 years).

FTA's Cost Per Hour of User Benefits

One measure of cost-effectiveness is cost per hour of user benefits, which is used specifically by the Federal Transit Administration to evaluate projects applying for funding from the New Starts program. FTA defines cost as the annualized incremental capital cost of the project plus the incremental operating and maintenance cost of the transit system in the forecast year (currently 2030). FTA defines user benefits as the equivalent hours of travel-time savings associated with improvements in transit service levels for all users of the transportation system. In contrast to the capital-cost-only measures presented above, FTA's measure clearly incorporates both capital and operating costs. However, the FTA measure is clearly of interest for two reasons. First, FTA's project effectiveness measure (with or without operating costs) offers all of the characteristics of the cost-effectiveness measures identified above. Second, FTA currently rates projects seeking federal funding assistance based on this cost-effectiveness measure (i.e., high, medium-high, medium, medium-low, and low). By using FTA's measure, U.S. transit operators can evaluate the relative cost effectiveness of alternative BRT investments and can also determine how each project would likely rate within FTA's New Starts process.

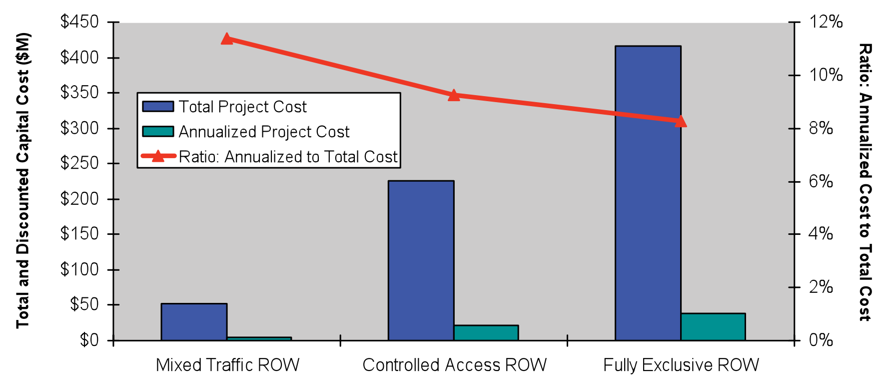
The Effects of BRT Elements on Cost Effectiveness

System Effects

By analyzing capital cost effectiveness, planners and decision-makers can identify mixes of BRT elements that deliver the desired service quality characteristics (e.g., passenger throughput) in the most cost-effective manner. Two examples show how capital cost-effectiveness measures can be used to help identify a preferred investment solution, one for a corridor with low ridership potential and one for a corridor with high unmet transit demand. These examples are only illustrative of the process.

The first case considers a BRT corridor with modest ridership potential. More specifically, it is assumed that, while ridership demand in this corridor is sufficient to warrant investment in BRT, total potential demand is relatively low as compared to other potential BRT corridors and as such will respond only minimally to increasing levels of investment in BRT (to further improvements to travel time, for example). This situation is presented in Exhibit 4-3.

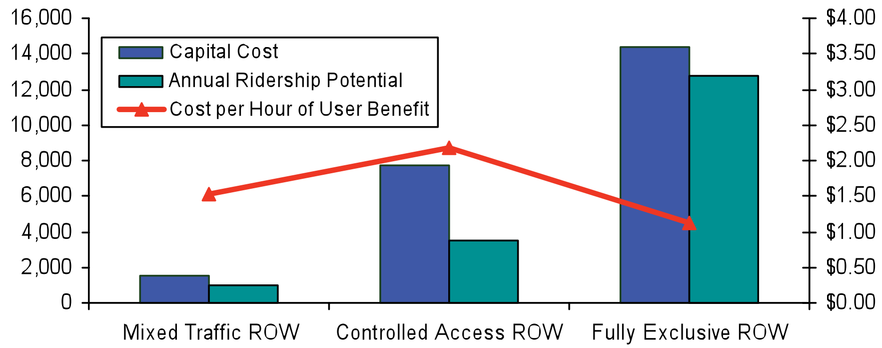
Exhibit 4-3: Cost Effectiveness Analysis Example for Corridor with Limited Ridership Potential



Here, the cost per hour of user benefits (FTA's cost-effectiveness measure) is calculated for varying levels of investment in BRT, including a simple mixed traffic investment (low cost), a higher throughput-controlled access BRT investment ("mid-level" cost), and a high throughput, fully-exclusive running way alternative (high cost). Because the corridor has limited ridership potential, project cost effectiveness declines with investment in BRT improvements within that corridor. Hence, for this example, investment in a mixed-traffic right-of-way solution appears to be the most cost-effective option.

A second corridor, illustrated in Exhibit 4-4, has relatively high ridership potential. Moreover, in this example, ridership is very responsive to "higher"-level investments in BRT (i.e., riders are responsive to additional investments that improve travel time savings and system throughput). For this example, investment in the more expensive, fully-exclusive guideway option appears to be the most cost effective (given its ability to service the high level of travel demand in the corridor).

Exhibit 4-4: Cost Effectiveness Analysis Example for Corridor with Limited Ridership Potential



In practice, each potential BRT investment will face its own tradeoffs between total ridership potential, ridership responsiveness to improvements to speed and throughput, and overall costs. Here, the characteristics of all projects will be different, with each requiring its own independent analysis. The point is that project cost-effectiveness analysis provides a valuable tool in identifying which mix of BRT elements and attributes meet the transportation needs of any given corridor in the most cost effective manner.

Effects by Element

On the cost side, project capital cost effectiveness is driven by the selection of BRT elements and the characteristics of those elements. In general, elements designed to support greater passenger throughput will have higher capital costs as compared to lower throughput alternatives, which may reduce project cost effectiveness (e.g., if the higher throughput option does not attract sufficient ridership). As a result, it is important for planners to analyze the primary drivers of capital costs (and, in turn, capital cost effectiveness) for BRT investments while considering which of those costs are subject to the greatest variability and thus pose the greatest risk to project costs. Exhibits 4-5 and 4-6 address these issues for two different BRT investment examples, the first being a "low level" BRT investment using lower-cost mixed traffic running ways and unadorned stops (Exhibit 4-5) and the second being a "higher-level" and higher-cost example using fully exclusive ROW and stations with passenger amenities (Exhibit 4-6). These examples are based on cost data from prior BRT and LRT projects.

Exhibit 4-5: Capital Cost Drivers and Sources of Cost Variability – Low-Level BRT Investment

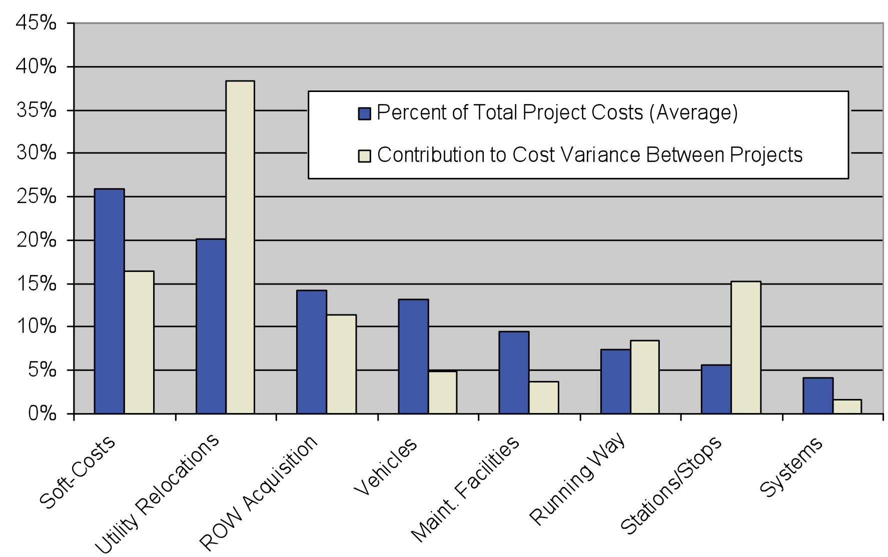
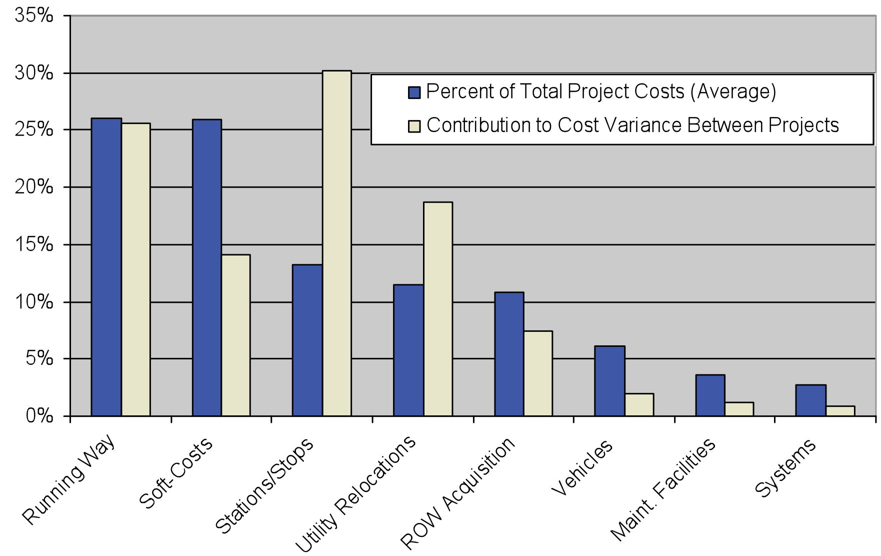


Exhibit 4-6: Capital Cost Drivers and Sources of Cost Variability – High-Level BRT Investment



For lower throughput BRT investments with relatively simple design characteristics (Exhibit 4-5), capital costs tend to be dominated by project soft costs (including the cost of project design, construction management, project oversight, testing, and start-up) and utility relocations and betterments (even projects with relatively modest improvements to existing roadways to accommodate BRT traffic tend to require material changes to existing public and private utilities including sewer and drainage, power distribution, gas lines, and telecommunications lines). Right-of-way acquisition and vehicle purchases should also be expected to be among the larger contributors to project costs, but to a lesser extent as compared to either soft costs or utility relocation costs. For these simpler BRT investments, the greatest sources of variation in costs between projects are expected to originate from project soft-costs and utility relocations, and also from station/stop costs. These variations in cost reflect differences in conditions encountered once construction has been initiated (e.g., utility adjustments may prove to be more or less costly than originally anticipated) and differences in design standards between projects (e.g., station/stop designs and amenities vary widely between projects).

In contrast, for higher throughput BRT investments (Exhibit 4-6), capital costs tend to be driven primarily by running way costs, project soft costs, and likely station costs. This difference, as compared to the earlier example, reflects the significantly higher level of investment in civil structures for higher throughput systems, including the cost of exclusive running ways (including barriers and potentially with grade separated crossings) and "complete" passenger stations with station structures, passenger amenities, parking access, and other features. Utility relocation and right-of-way acquisition costs can also be expected to be among the higher-cost items for high-throughput BRT investments. For these project types, the greatest source of cost variation originates with station costs (given the broad array of potential station design options) as well as from running way investment costs (with the potential for some grade separation including tunnels) and utility relocation needs.

The summary below presents considerations related to individual BRT elements.

- ***Running Ways***—Running ways often constitute the most significant potential capital costs, depending on the level of separation from other traffic that the BRT implementation demands (costs increase with the level of separation). The least costly running-way option is to provide BRT service in mixed-flow lanes, similar to conventional bus service, but with the possible addition of queue jumps. This solution does not involve any right-of-way acquisition, road construction, or pavement re-striping. With increasing segregation of BRT service from other traffic, however, costs, requirements for cooperation with other stakeholders, and environmental mitigation efforts increase. A designated arterial lane requires improved signage, pavement re-striping, and installation of physical barriers. New segregated lanes in medians can cost between $2.5 and $2.9 million per mile (excluding ROW acquisition, which may also be necessary). The most expensive running way options are exclusive transitway lanes, which can be either at-grade or grade-separated. While these options offer significant potential for speed and reliability, they cost between 3 and 20 times more than designated arterial lanes. Even modest improvements to existing roadways to accommodate mixed BRT and auto traffic will require material relocations or improvements to existing public and private utilities. Public or "wet" utilities (e.g., water and sewer systems), private or "dry" utilities (e.g., power, telecommunications, and gas lines) can represent a large proportion of total project costs (particularly for lower throughput investments). These costs tend to vary widely between projects and even segments of the same project. This variation reflects the unique character of utility networks encountered for each project, some of which is driven by differences in the density of urban development (with higher development requiring higher needs) and the age of the utility networks (with older networks more likely to require a utility upgrade).

- ***Stops/Stations***—BRT stops/stations vary widely in concept, ranging from simple raised-platform bus stops to large transfer centers, and stop/station costs vary widely to reflect these differences. The cost of a station is largely driven by its size, which, in turn, is driven by the number and frequency of routes serving the station. Stop/station costs are also significantly impacted by the inclusion of an enclosed station structure, passenger amenities (e.g., bathrooms, elevators, escalators), and external station access (e.g., pedestrian overpasses, parking).
- ***Vehicles***—Cost increases with the complexity of the vehicle configuration, the addition of enhancements, and the sophistication of the propulsion system. Specialized BRT vehicles cost the most. Other than right-of-way acquisition and exclusive running-way construction, vehicles constitute the most significant capital investment for a BRT deployment.
- ***Fare Collection System***—BRT fare collection is often integrated with the fare collection systems of the broader transit network. Decisions about system-wide fare collection may be driven by the needs of the BRT element or made independently of any BRT-specific needs. Consequently, measuring the cost of fare collection systems as part of a cost-effectiveness assessment must consider the relative costs and benefits of fare collection that are specifically attributable to the BRT component of the broader regional transit system.
- ***ITS***—The role of ITS is to facilitate and improve the management and performance of the BRT system. Like fare collection systems, ITS often requires application across an entire transit or traffic system to be justified. System-wide benefits of ITS application are relevant for analyses of capital cost effectiveness.

Other Factors Affecting Capital Cost Effectiveness

Several external factors affect capital cost effectiveness:

- ***Labor and Materials Costs***—The strength of the local economy will determine the relative cost of labor and materials and will create regional differences in the costs to develop BRT systems; the global economy is playing an increasing role in the rise of materials costs, especially of steel and concrete.
- ***Property Costs***—Because running ways and stations comprise some of the larger expenses in developing BRT, they play a large role in the ability to develop cost-effective BRT solutions; regions in which right-of-way and property are very expensive will experience higher cost systems.
- ***Performance of the Transportation System***—The performance of the existing transportation system drives how much benefit a new BRT system investment can bring; introducing a superior BRT system into an environment with a highly-congested transportation system or a low-speed, unreliable transit system can reap significant benefits to justify an investment.

Summary of Impacts on Capital Cost Effectiveness

Exhibit 4-7 presents the capital costs for a selection of recently-implemented BRT systems in the U.S. Because of the wide variability in labor, materials, real estate, and other costs in different regions of the world, this report will not compare capital costs of other worldwide BRT systems.

The variation in capital costs among these systems reflects the wide variety of BRT system design strategies employed by U.S. transit agencies. The tendency to use simple running way treatments results in relatively low overall capital costs for most of these BRT systems. The Boston Silver Line Waterfront service and the Orange Line in Los Angeles are the main exceptions. The Orange Line demonstrates the high costs of building an off-street dedicated transitway, while the Silver Line Waterfront reflects the extremely high cost associated with the underground tunnel and three underground stations.

Most of the U.S. systems focus significant investment dollars in stylized and high-capacity vehicles. For the Boston Silver Line Washington Street, the Eugene EmX, the Las Vegas MAX, and the Sacramento E-Bus, the vehicles represent one-third to one-half of the total budget. The Orange Line and Waterfront service also have very high vehicle costs. By contrast, the Los Angeles Metro Rapid service

Exhibit 4-7: Capital Costs for Selected Recently-Implemented U.S. BRT Systems

City	Boston		Eugene	Las Vegas	Los Angeles		Sacramento	San Jose
BRT Line / System	Silver Line Washington St	Silver Line Waterfront	EmX	MAX	Orange Line	Metro Rapid (All Routes)	EBus - Stockton	Rapid 522
Year of Opening	2002	2005	2007	2004	2005	2000-today	2004	2005
Length of Route (mi)	2.4	4.5	4.0	7.5	14.5	229.5	8.0	25.0
Total Capital Cost by Route	$27.29 m	$618 m	$23.5 m	$20.16 m	$318 m		$7.95 m	$3.5 m
Running Way	$8.44 m	$572.2 m	$18 m for all design and construction	$0.04 m	$180 m			$2.7 m
Stations	$5.0 m	included in Running Way		$5.45 m	$40 m	$50,000 per station	$0.80 m	minimal, used existing stops
Vehicles	$13.85 m	$42.2 m	$6.5 m	$12.10 m	$16 m	$350,000 per bus	$3.8 m	$130,000 to wrap existing vehicles
ITS			Included in $18 m	$0.57 m	$10 m	$100,000 per mile	$1.8 m	Included in other VTA projects
Fare Collection				$2.00 m	$6 m			No extra investment needed
Other		$9.60 m			$66 m		$1.55 m	$550k for planning and project management

and the San Jose Rapid chose to use the same vehicles acquired for their regular fleet, so the only additional vehicle costs are associated with the distinct livery.

The System Performance Profiles below provide greater detail on the varying capital cost strategies of several U.S. BRTs.

System Performance Profiles

Metro Rapid and Orange Line, Los Angeles

Two BRT systems in Los Angeles demonstrate differing approaches to investing in BRT elements to improve performance and attract riders. The strategy for the Metro Rapid network was to implement relatively easy and low cost upgrades to conventional bus service. The program invests in enhanced stations, with real-time passenger information, and transit signal priority to improve travel times in mixed traffic. The Metro Rapid vehicles are primarily 40-ft and 45-ft Metro fleet vehicles that have a red/silver two-tone paint scheme & Metro Rapid name branding. By using existing roadways, on-board fare collection, and fleet vehicles that require only a distinct livery, the transit agency has been able to keep the program's costs quite low – the agency estimates that it costs $50,000 per station and $100,000 per mile for the ITS treatments. This low investment level has enabled the agency to implement these features across a large network of more than 220 miles (with new lines being opened on a regular basis, the total network length is constantly increasing). The agency reports that, on average, travel times have been reduced by 25 percent, and ridership across the entire network has increased by 20 percent.

The Orange Line BRT represents a very different strategy. With the Orange Line, the transit agency made a significant investment in deploying all features associated with a BRT system in a single 14-mile corridor. The corridor primarily follows an existing ROW on an abandoned rail line; the transit agency had long planned to implement a rail rapid transit line in this corridor to serve the San Fernando Valley area and offer an alternative to the congested highway (US-101) that runs parallel to the corridor. This strategy required relatively high investments for all BRT components, including a dedicated running way; stations with real-time information and substantial passenger amenities; high-capacity CNG vehicles; off-board fare collection; and landscaping, bike and pedestrian paths, and park-and-ride lots. Total capital costs were $318 million, or $22.7 million per mile (these costs do not include the ROW acquisition, as this occurred long before the decision to implement BRT). The Orange Line has surpassed the agency's original ridership projections, with a reported 51 percent increase in corridor ridership. End-to-end travel time has been reduced by only 16 percent, mainly due to safety concerns surrounding the at-grade intersections which require drivers to slow down considerably when driving through each intersection.

Silver Line Washington Street, Boston

The Silver Line Washington Street service is another example of using existing roadways to keep overall capital costs down. The cost of shelters, kiosks, stop amenities, and roadway work associated with the project was just $13.4 million, or $2.84 million per directional route mile. The project realized significant cost savings by being planned and constructed in conjunction with street reconstruction supported by state highway funding. By combining these two efforts, the MBTA not only saved costs, but also supported the Washington Street renovation that has helped drive development along this corridor. The agency also saved costs by contracting the construction of one Silver Line shelter to a company that then uses revenue from advertising on stations to pay for the construction and on-going maintenance. The articulated vehicles were the most expensive single component; at $13.85 million, they constitute half of the total capital expenditure.

OPERATING COST EFFICIENCY

Benefit of Operating Efficiency

Two of the distinguishing attributes of BRT are its adaptability to meet the specific needs of an existing transit network and the ability to achieve high levels of operational efficiency at relatively low capital costs. Hence, as with capital cost efficiency, it is helpful to assess the operating cost efficiency impacts of investment in various combinations of BRT elements and complementary service plans to help identify the most cost effective investment options for any given travel corridor. The purpose of this section is to demonstrate the impact of BRT system design elements on operating efficiency. To do this, it is useful to define how operating efficiency is measured and to define key performance indicators that can be used to monitor operating efficiency and productivity.

Definition of Operating Efficiency

Operating efficiency is the ability to produce a unit of service output from a unit of input. Examples of operating cost efficiency measures include cost per vehicle hour of service or cost per passenger. The operating efficiency of a BRT system is influenced by the interplay of four critical factors: capital investment choices, operating plan choices (number of service hours), service pricing, and system ridership. Capital investment choices, operating plan choices, and service pricing represent decisions the BRT investor/operator can make to ensure the most efficient service possible. In contrast, the level of system ridership, while influenced by agency service design and pricing decisions, is ultimately the decision of transit riders.

Measures of Operating Efficiency

Measures of operating efficiency and productivity applied to BRT are common to the transit industry and enable a comparison between BRT and other local fixed route service and among BRT systems nationally. Examples of performance indicators used as part of an ongoing performance measurement system include:

- subsidy per passenger mile
- subsidy per passenger
- operating cost per passenger
- operating cost per vehicle service mile (VSM)

- operating cost per vehicle service hour (VSH)
- passengers per VSH
- passengers per VSM
- VSH per full-time equivalent (FTE) employee

Operating efficiency also can be measured in terms of dimensions of service quality. For example, BRT systems that operate on exclusive running ways and have stations with level platform boarding realize operating efficiencies that cannot be achieved by BRT systems that operate along mixed-flow lanes with uneven platform boarding. In the latter BRT scenario, running times are less reliable, station dwell times tend to be longer, and end-to-end travel times tend to be longer. To compensate for high variation in system performance, the BRT operating and service plan may involve increased service frequency levels, especially in the AM and PM peaks, specifically to mitigate schedule adherence problems. In this case, operating inefficiencies result in service input requirements that are higher than would otherwise be needed.

The Effects of BRT Elements on Operating Efficiency

As noted above, capital investment choices and operating plan choices represent variables the BRT investor/operator can control. The relationships between the first two factors and BRT operating costs are outlined in Exhibit 4-8.

Exhibit 4-8: Decisions Impacting Operating Cost Efficiency

Capital Investment Choices (Differing BRT Configurations)	Operating Plan Choices (Different for Same BRT Configuration)
Level of Separation	Service Headways
- mixed traffic vs. dedicated ROW	- total operating cost
- operating speeds	- ridership
- running way maintenance requirements	Non-Productive Vehicle Hours (e.g., layover)
Fare Collection and Fare Structure	- cost per revenue hour
- automated vs. staffed kiosks	Stations Manned?
- proof of payment vs. access-controlled system	- labor costs
- stored value vs. single ride (zonal vs. flat fares)	Administration / Overhead
Vehicle Size / Capacity	- total operating cost
- cost per passenger	

Capital Investment Choices

Capital investment decisions have varying implications for the subsequent operating costs and operating cost efficiency of the completed system. They determine the throughput and other physical characteristics of the completed BRT network. Examples include decisions regarding vehicle size/capacity, the use of staffed versus unstaffed stations, and the use of mixed traffic or exclusive running ways. Each of these capital investment choices has implications for the operating costs of the completed system, and it is generally the case that operating costs tend to increase as the level of investment in BRT element increases. For example, dedicated right-of-way maintained by the operating agency will be more expensive to operate and maintain than shared traffic right-of-way, where the cost of maintenance activities is shared with the local city transportation department. Similarly, heightened investment in supporting ITS investments requires sufficient staffing resources to operate and maintain these systems. Large passenger stations with station attendants, passenger amenities, and parking facilities are more expensive to operate and maintain than unstaffed stops with a shelter and raised platform.

Operating Plan Choices

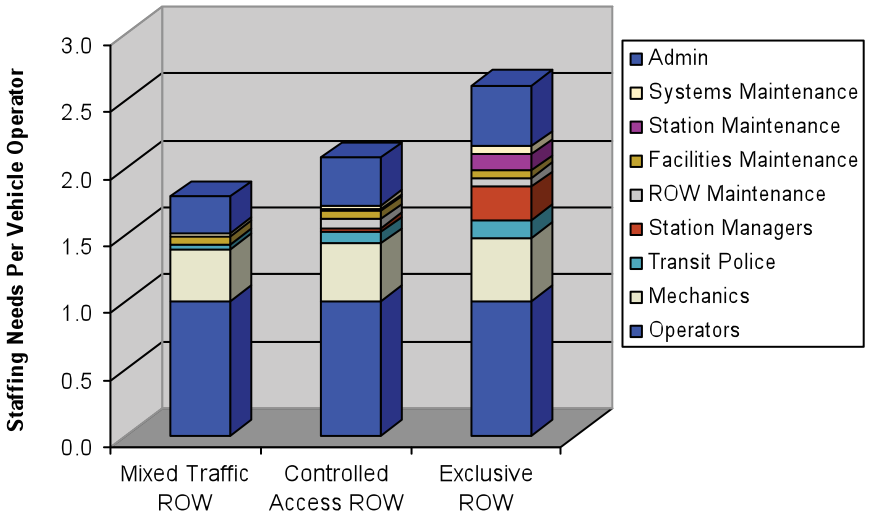
Operating plan choices include decisions regarding the service hours, service frequency (scheduling), route design, and other service design characteristics of the completed system. For the most part, the principles appropriate to the design and scheduling of cost-efficient BRT service are no different than for conventional bus or rail services. As with conventional bus service, service planners should design service that is appropriate to the level of travel demand and that minimizes non-productive vehicle hours (i.e., paid operator time when the vehicle is not in service). The key difference with conventional bus service relates to the potential need for additional staff, depending on service design characteristics. Examples include the need for roving fare inspectors for "proof-of-payment" fare systems and station attendants for large passenger stations and transfer centers.

Other Factors Affecting Operating Efficiency

Labor Costs

Regardless of a BRT system's physical or operating characteristics, operating costs will be dominated by labor (wage and benefits) costs. Hence, differences in costs (and operating cost efficiency) between BRT investments primarily reflect differences in labor requirements based on capital investment and operating plan choices. For example, for conventional bus service and light rail operations with unmanned stations, labor costs make up roughly 70 percent of total operating costs, with the cost of fuel, parts, equipment, and services making up most of the balance. In contrast, for U.S. rail systems with manned stations, agency labor costs make up more than 80 percent of annual operating costs. This relationship is further illustrated for the BRT context in Exhibit 4-9.

Exhibit 4-9: Labor Staffing Requirements for Alternative BRT Investments



Source: Comparison of bus and rail budget data from WMATA

The exhibit presents illustrative examples of total staffing needs for BRT systems with differing configurations (i.e., for mixed traffic, controlled access, and exclusive ROW alternatives). As with earlier examples, this comparison assumes increasing investment in BRT elements moving from the mixed traffic alternatives to the exclusive right-of-way alternative. In particular, it is assumed that the mixed traffic alternative uses simple raised platform stops, conventional on-board fare collection, and minimal investment in ITS. In contrast, the exclusive ROW alternative is assumed to include several large and manned stations, roving fare inspectors, and heightened investment in ITS systems (such as real-time passenger information displays and kiosks). The controlled-access ROW alternative represents a mid-point between these two extremes. The differing staffing needs for these alternatives are represented here as the ratio of the full-time staffing count required for each operational function to the number of vehicle operators required to maintain comparable service levels for each alternative. (In other words, for each full-time vehicle operator delivering service, the mixed traffic alternative requires roughly 0.7 additional staff FTE's to support BRT operations, including vehicle mechanics, transit police, and administrative staff; in contrast, the exclusive ROW requires 1.5 additional, non-operator staff per operator.) The point to note here is that the lower-complexity BRT investments require less labor to deliver comparable levels of service frequency (if not the same service quality) as compared to more complex BRT investments. However, higher speeds on busways may need fewer operators for a given level of service demand.

To summarize briefly, capital investment and operational design choices both have material impacts on the operating costs and operating cost efficiency of BRT investments. Potential BRT system planners should carefully consider and evaluate these potential cost implications when identifying the best mix of BRT elements to meet the specific transportation needs of any given transportation corridor.

System Performance Profiles

The following performance profiles demonstrate the determinants of operating costs for a selection of U.S. BRT systems. Because of the wide variability in labor and other costs in different regions of the world, this report will not compare operating costs for other worldwide BRT systems.

Metro Rapid Wilshire-Whittier, Los Angeles

The Metro Rapid Wilshire–Whittier line in Los Angeles operates in the highest density transit corridor in the region. Before the implementation of Metro Rapid, a combination of seven local and limited service lines operated in the corridor (five in the Wilshire Boulevard corridor and two in the Whittier Boulevard corridor). In terms of service effectiveness and efficiency variables, Metro Rapid improved the performance of transit service in the corridor, as shown in Exhibit 4-10.

Exhibit 4-10: Operating Efficiencies in the Wilshire–Whittier Metro Rapid Corridor (as of 2002)

Route	Passengers per Revenue Hour		Subsidy Per Passenger Mile		Subsidy Per Passenger	
	Before Metro Rapid	After Metro Rapid	Before Metro Rapid	After Metro Rapid	Before Metro Rapid	After Metro Rapid
18 / 318*	62	63	$0.17	$0.18	$0.51	$0.46
20 / 21 / 22 / 320* / 322*	43	61	$0.21	$0.15	$1.08	$0.58
Metro Rapid 720		57.2		$0.14		$0.82
Combined	51	59.7	$0.20	$0.15	$0.79	$0.65

** Service eliminated after implementation of Metro Rapid*

Metro Rapid's implementation increased the service productivity from 51 passengers per vehicle revenue hour to 59.7 passengers per vehicle revenue hour. It also reduced corridor subsidies related to both passenger miles and total passengers. Note that the Metro Rapid service increased the combined efficiency of service operated in that combined passengers per revenue hour increased and combined subsidy per passenger and per passenger mile decreased. The benefit of Metro Rapid is that it improved performance measures for the corridor transit service as a whole (Transportation Management & Design, Inc., 2002).

West Busway, Pittsburgh

The West Busway in Pittsburgh demonstrated the following performance measures for operating cost efficiency and cost effectiveness, as illustrated in Exhibit 4-11 and Exhibit 4-12 (U.S. Department of Transportation 2003):

Exhibit 4-11: Performance Measures for Pittsburgh West Busway Operating Cost Efficiency (veh mi per veh hr)

Operating Cost Per:	
Vehicle revenue mile	$6.40
Vehicle revenue hour	$81.90
Passenger mile	$0.65
Unlinked passenger trip	$2.73

Martin Luther King Jr. East Busway, Pittsburgh

The speed of the East Busway allows more vehicle miles of service to be operated with the same number of vehicle hours, which drive major operating costs such as labor costs. This is because operating speeds are higher.

Exhibit 4-12: Performance Measures for Pittsburgh East Busway Operating Efficiency (veh mi per veh hr)

Route Type	Vehicle Miles per Vehicle Hour
New routes	15.8
Routes diverted to East Busway	19.6
Other routes in system	11.5

The comparison of vehicle miles per vehicle hour shows that routes on the East Busway are able to generate between 37 and 70 percent more vehicle miles from each vehicle hour (Pultz and Koffman 1987). An analysis performed by Port Authority Transit (now Port Authority of Allegheny County) assigned operating costs to transit trips and calculated operating cost parameters for different types of routes.

Exhibit 4-13: Operating Cost per Service Unit by Type of Route for Pittsburgh East Busway (1983 $)

Performance Measure	Ridership	New Routes	Diverted Routes	All Other Routes in System
Cost Effectiveness	Per passenger trip	$0.76	$1.95	$1.27
	Per peak passenger trip	$1.32	$3.19	$3.09
	Per passenger mile	$0.15	$0.37	$0.24
	Per peak passenger mile	$0.27	$0.60	$0.58
Cost Efficiency	Per seat mile	$0.06	$0.06	$0.07
	Per peak seat mile	$0.12	$0.09	$0.16
	Per vehicle vile	$3.61	$2.58	$3.26

The analysis shows that new routes and diverted routes on the busway operate with higher operating efficiencies with respect to capacity operated (seat mile and peak seat mile). Diverted routes have lower operating costs per vehicle mile than other non-busway routes. (The higher cost of operating vehicle miles for new routes can be attributed to the fact that those routes are operated with articulated vehicles.) Furthermore, new routes have higher cost effectiveness, with lower costs per unit of service consumed across the board, especially since demand is close to the operated capacity. Diverted routes demonstrate lower cost effectiveness since they tend to generate demand further below capacity than other routes (Barton-Aschman 1982).

Silver Line Washington Street and Waterfront Service, Boston

A comparison of the Silver Line Washington Street service with the previous local bus service in the corridor and MBTA's systemwide bus service demonstrates how BRT's greater ridership intensity can improve operating cost efficiencies even if the costs per vehicle mile are higher.

The Silver Line's costs are higher on a per vehicle mile basis, largely due to the higher cost of CNG over diesel fuel used by the previous local bus service and by the rest of the MBTA fleet. However, the Silver Line has much higher usage than the other local services. As a result, MBTA is providing less of a rider subsidy for the Silver Line service than for its local routes.

Early results for the Silver Line Waterfront service show a higher passenger subsidy rate due to the lower ridership levels than on the Washington Street service. Two of the Waterfront lines operate in corridors not previously served by transit, and the Waterfront area is still in the early stages of a major redevelopment boom. Therefore, current ridership is lower than would be expected when the new developments open.

Exhibit 4-14: Comparison of MBTA Silver Line Washington Street Operating Costs

	Cost per Vehicle Mile	Cost per Vehicle Hour	Passengers per Vehicle Hour	Cost per Passenger	Revenue per Passenger	Differential
Silver Line	$17	$109	117.4	$0.92	$0.42	($0.50)
Rt. 49	$13	$102	99.5	$1.03	$0.48	($0.55)
System	$10	$102	51.2	$1.99	$0.53	($1.46)

Source: 2004 MBTA Service Plan

Exhibit 4-15: MBTA Silver Line Waterfront Operating Costs, Early Results

Cost per Vehicle Mile	Cost per Vehicle Hour	Passengers per Vehicle Hour	Cost per Passenger	Revenue per Passenger	Differential
$11	$142	76	$1.88	$1.15	($0.73)

TRANSIT-SUPPORTIVE LAND DEVELOPMENT

Benefit of Transit-Supportive Land Development

Like other forms of rapid transit, BRT has a potential to promote transit-supportive land development, promoting greater accessibility and employment and economic opportunities by concentrating development, increasing property values, and creating more livable places. BRT corridors serve both existing land use and have the ability to create new land forms along the transit system. Definition of Transit-Supportive Land Development

Definition of Transit-Supportive Land Development

Investment in public transit facilities such as stations or other transit infrastructure improves accessibility and attracts new development. Transit-supportive land development leverages the characteristics of transit—regular and frequent flows of pedestrians and customers. There are several characteristics of transit-supportive land development. Typically, this development has higher densities and intensity of use. The mix of land uses is more diverse, including housing, employment, retail, and leisure activities. There is less emphasis on automobile-oriented uses and automobile access (less parking).

Transit-supportive land development creates many additional benefits. In many BRT systems, transit-oriented development is being used as a tool to encourage business growth, to revitalize aging downtowns and declining urban neighborhoods, and to enhance tax revenues for local jurisdictions. These benefits contribute to a net regional economic benefit. Most important, these benefits, in turn, generate a direct net impact for transit system customers by allowing increased access to jobs and other services as well as improved mobility.

Measures of Transit-Supportive Land Development

There are several ways to gauge how BRT enables transit-supportive land development. For the purposes of this report, three ways are presented: actual impacts to the quantity of development around transit, actual impacts to the character of development, and the extent of changes to land use and development policy.

Quantity of New Development

The quantity of new development is usually presented as the amount of new development within a certain distance of a transit station or transit running way alignment. Although there is no uniform measure of quantity of new development for comparison corridors, common measures include gross square footage, number of housing units, new population accommodated, and new jobs accommodated. The area of reporting is sometimes represented as one-quarter or one-half mile from transit stations or transit alignments.

Character of New Development

The character of new development incorporates many concepts such as land use mix, extent and quality of pedestrian infrastructure and the scale of development, and the extent to which uses are pedestrian-oriented and not automobile-oriented. Due to the qualitative nature of these characteristics, there is no uniform way to represent the character of new development. Simple measures indicate whether land uses are mixed or not and whether pedestrian infrastructure is provided.

Changes to Land Development Policy

Changes to land development policy are difficult to characterize. Often, the strength of transit-supportive policies can be rated. For this document, it is reported whether or not a local agency has adapted land development policy as a result of or in anticipation of implementation of a BRT system.

Effects of BRT Elements on Transit-Supportive Land Development

Specific design elements of a BRT system, particularly those that involve physical infrastructure investment, each have positive effects on land use and development.

Running Way

Research shows that the effect of investments in running ways is three-fold:

- They improve the convenience of accessing other parts of a region from station locations.
- Increased accessibility increases the likelihood that property can be developed or redeveloped to a more valuable and more intense use.
- Physical running way investments signal to developers that a local government is willing to invest in a significant transit investment and suggest a permanence that attracts private investment in development.

Stations

Station design can have significant impacts on the economic vitality of an area. A new BRT station provides opportunity to enhance travel and create a livable community at the same time. Station designs that effectively link transit service to the adjacent land uses maximize the development potential. It is important to note that the inclusion of routes in BRT systems that combine feeder service and line-haul (trunk) service reduces the need for large parking lots and parking structures, thereby freeing land at accessible locations for development.

Vehicles

Vehicles can reinforce attractiveness (and, indirectly, the development potential) of BRT-adjacent properties to the extent that they:

- demonstrate attractive aesthetic design and support brand identity of the BRT system
- suggest a willingness on the part of the public sector to invest in the community
- reduce negative environmental impacts such as pollutant emissions and noise

Experience in Boston and Las Vegas suggests that developers do respond to services that incorporate vehicles that are attractive and that limit air pollutant and noise emissions. Successful developments in Pittsburgh and Ottawa, where more conventionally-designed vehicles are deployed, suggest that development can still occur with all vehicle types as long as service improvements highlight the attractiveness of station locations.

Service and Operations Plan

The flexible nature and high frequencies of BRT service plans allow it to expand or contract with changes in land use quickly and easily. If the BRT is designed to provide fast and convenient connections among key activity hubs in an urban or suburban area, this may help attract developer interest.

Other Factors Affecting Transit-Supportive Land Development

Policy and Planning

In most cases, transit agencies in the United States do not have direct authority to plan or direct the development patterns of areas around stations of their systems. Land development policy is usually the responsibility of local municipal agencies. Land development policy and planning instruments, such as plans and zoning codes, determine several characteristics that affect development:

- land use intensity
- mix and variety of uses
- guidelines for site planning, architecture, pathways, and open spaces that affect the pedestrian-oriented nature of an area
- parking requirements

Transit agencies do often support standards that increase the transit market base – density bonuses, promotion of land use mixing, removal or relaxation of density caps, removal of height limits, and reduction of parking ratios.

Economic Environment

Transportation is a necessary condition for development but does not drive development. The rate of regional development is defined by the strength of the local economy. In addition to BRT system characteristics and local planning and zoning, the local economy drives how much development can occur. While the local economy is out of the control of transit agencies, they can play a role in directly supporting development projects.

System Performance Profiles

Projects discussed below illustrate the increasing relationship between BRT systems and transit-supportive development. This information is a compilation of qualitative and anecdotal data provided from transit agencies and local city officials.

Silver Line, Boston

Phase I of the Silver Line was developed along the Washington Street corridor, which originates from downtown Boston to the southwest. The Washington Street corridor is historically a strong corridor for development, owing to its history as the primary link between downtown Boston and towns to the south and west. Previously known as a "gateway" into Boston, it was once served by an elevated heavy rail line. The corridor had been economically depressed throughout the 1970s and 1980s and had seen derelict, abandoned, and demolished structures. Due to the 1973 "transit-first" policy, which increased investment in public transit, the elevated heavy rail line was removed from Washington Street between downtown and Dudley Square in 1987. For 10 years, the corridor was not served by rapid transit. Discussions were held to determine alternatives, and the decision to implement Boston's first BRT system, the Silver Line, was made. Removing the elevated structure, repaving the roadway, and improving the streetscape were seen as key elements to the revitalization of Washington Street. Throughout the planning and construction of the Silver Line Phase I project, development has accelerated along the corridor, resulting in at least $93 million in new development. Projects include a mix of retail, housing, and institutional uses, including police stations and medical facilities. Most projects include retail on the ground level.

Phase II of the Silver Line, the Waterfront service, connects South Station, which is also served by the Red Line subway, commuter rail, Amtrak, and inter-city buses, to Logan Airport and to the Seaport District. The Seaport District is a prime real estate development opportunity in Boston; until recently, it had been dominated by maritime uses and surface parking lots. The 1,000-acre site offers the city a chance to create the first new transit-oriented development neighborhood in decades. Massport, the state agency responsible for the management of airports, bridges, and port facilities, owns much of the property in this area. Along with the Boston Redevelopment Authority, Massport is working to promote dense mixed-use development and create a "new downtown." The Seaport District's transit orientation is being driven in part by a state-imposed parking freeze.

New development along Boston's Silver Line

The Courthouse, World Trade Center, and Silver Line Way stations are within walking distance of the majority of development. Massport and the MBTA are working with the site developers to ensure that the planned projects are integrated with the Silver Line stations. For example, the World Trade Center station was built jointly by the MBTA, Massport, and the local developer. Riders have direct pedestrian access into the World Trade Center complex from the Silver Line station. This same developer is working with Massport on a new project to be built in the air rights over the World Trade Center station and will have an entryway directly into the station (Breakthrough Technologies Institute 2008).

The Transitway, Ottawa, Ontario

Over one billion Canadian dollars have been invested in new construction around Transitway stations. Since 1987, the following construction projects were completed:

- In 1987, the St. Laurent Shopping Centre completed an expansion that included 80 additional retail outlets.
- Six new office buildings, a cinema complex, and a community shopping center have been constructed near Blair station since it opened in 1989.
- In 1991, the Riverside Hospital built an expansion over the Riverside station, and a pedestrian walkway was constructed to connect the station with a new medical office building.
- The regional planning department found that between 1996 and 1998, more than $600 million was spent on the construction of 3,211 residential units and 436,858 square meters of institutional and commercial buildings near Transitway stations.

From 1988 to 1993, more than 2,300 housing units were built within an 800-meter radius of 14 surveyed Transitway stations. The majority of this construction occurred near the Hurdman and Tunney's Pasture stations. The Tunney's Pasture station is surrounded by a federal complex that employs 10,000 workers. A large mixed-use project was built that featured a residential tower and 18,200 square meters of retail (located on the ground floor) and upper-level offices. The project received approval to lower the parking requirements, given its accessibility to the transit station. In addition, a significant amount of development has occurred around other stations along the Transitway, including the Blair, St. Laurent, and Riverside stations, and Rideau Center.

North Las Vegas MAX, Las Vegas

The North Las Vegas Boulevard corridor is a low-density corridor extending from downtown Las Vegas to the north. The system began operation in summer 2004. While general development patterns have still not yet transformed due to the brief period of operation, one casino has already invested in pedestrian facilities and an additional station to attract passengers from the system.

Orange Line, Los Angeles

Opportunities for development along the Metro Rapid Orange Line in Los Angeles are certain. A Revised Final Environmental Impact Report (RFEIR) for the Metro Orange Line concluded that the exclusive transitway operation of the Orange Line has potential land use benefits that would encourage transit-oriented development at or around stations and is consistent with adopted local planning documents. Potential redevelopment may be a consideration as well. The Community Redevelopment Agency of Los Angeles (CRA) invited the Urban Land Institute (ULI) to examine development opportunities in the core area of the CRA's North Hollywood Redevelopment Project, particularly at the North Hollywood Metro Red Line subway station. Near this station is the terminus for the Metro Orange Line. The North Hollywood community area was originally a farming community and eventually became a convenient residential area. Following freeway construction of the 1960s and 1970s, the area experienced decline, but redevelopment efforts have been made since 1979. Significant changes have occurred since the opening of the Red Line Metro subway station in 2000. This, in combination with the addition of the Metro Orange Line, has resulted in an increase in revitalization efforts. Commercial and residential investments have been made, and developers have continued to express interest as well. NoHo Commons, a multi-phased mixed-use complex several blocks east of the North Hollywood Metro Rail Station, features 220,000 square feet of office space, 228,000 square feet of shops and restaurants, 810 units of housing, a community health center, and a child-care center.

LYMMO, Orlando

LYMMO plays a vital role in the economic development of downtown Orlando. Numerous commercial and residential developments have been built since the inauguration of the LYMMO BRT service. By providing a high-quality, frequent, and reliable transportation choice for downtown employees, visitors, and residents, LYMMO has increased accessibility to public transit. The City of Orlando makes use of LYMMO as a tool to promote development. As a possible result of this strategy, there are five new office buildings in Downtown Orlando with about one million square feet per building. In addition, six new apartment communities have recently been developed in downtown Orlando (National Bus Rapid Transit Institute 2003).

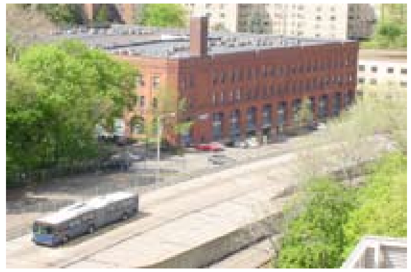
West Busway, Pittsburgh

The Port Authority of Allegheny County has advertised for joint development opportunities with those interested in using agency-owned land for plans compatible with adjoining park-and-ride lots. Despite the difficult development conditions (narrow railroad corridor with limited commercial activity), some development has been generated. The Borough of Carnegie has constructed a municipal building, including retail services, adjacent to a 215-space park-and-ride lot at the terminus of the West Busway. The Port Authority also has solicited development at the West Busway's Carnegie Borough Park-and-Ride and a park-and-ride lot in Moon Township near Pittsburgh International Airport. The Moon Township development is notable since it demonstrates how the flexibility of BRT enables the benefits of transit to be transferred to locations not directly adjacent to the major transportation facility (U.S. Department of Transportation 2003).

Martin Luther King Jr. East Busway, Pittsburgh

From its inception, the East Busway was envisioned by state and local officials to stimulate development through the eastern Pittsburgh suburbs. Early efforts included promotion of development and designation of "Enterprise Development Areas" in the municipalities of East Liberty and Wilkinsburg (Pultz and Koffman 1987). Fifty-four new developments have occurred within 1500 feet of stations. Overall, the East Busway corridor, since its opening, has experienced approximately $500 million in land development benefits.

Negley (Shadyside)



East Liberty (Shadyside)

EmX, Eugene

In Eugene, Oregon, the Lane Transit District (LTD) and city planning agencies have begun planning exercises to encourage higher density development around EmX stations. Enhanced bicycle and pedestrian connections address a number of traffic issues and provide a more pedestrian-friendly environment. In December 2006, a 13-acre parcel at the northwest corner of International Way and Corporate Way was sold for $5.8 million. Plans for the property include dividing it into six different parcels. It was said that the property had generated a lot of interest, largely because of its location along the EmX route.

Euclid Avenue HealthLine, Cleveland

Real estate development along Cleveland's Euclid Avenue received a major boost when plans were unveiled for a BRT line. The presence of identifiable station structures was cited as a key reason for this speculative development. Part of this interest may be attributed the fact that the project includes a complete streetscape renovation by the Greater Cleveland Regional Transit Authority (GCRTA); streetscape enhancements, including pedestrian scale sidewalk lighting, will enhance the pedestrian character of the Euclid Corridor and complement the recent redevelopment efforts within this area. In February 2008, a *Cleveland Plain Dealer* article estimated that more than $4.3 billion in economic investments have occurred or are planned along this corridor. The article noted the key role that the Euclid Corridor project had played in revitalizing this area.

ENVIRONMENTAL QUALITY

Benefit of Environmental Quality

Environmental quality represents a variety of indicators reflecting the local urban and natural environments, public health, and the global environment.

BRT can improve environmental quality through a variety of means, but the most significant impacts are reduced vehicle emissions of local air pollutants, greenhouse gas reductions, and increased vehicle fuel efficiency. BRT systems may produce these impacts through three mechanisms that affect the emissions and fuel consumption of both the BRT vehicles and other vehicles operating around the transit corridor:

- ***Vehicle technology***—Many U.S. BRT systems use alternative fuel vehicles, primarily compressed natural gas and diesel-hybrid. New diesel buses also have very low emissions due to stringent federal heavy-duty diesel engine emissions standards going into effect from 2007 to 2010.
- ***Ridership and mode shift***—BRT systems in the U.S. are attracting drivers to transit. Shifting trips from private cars to BRT lowers regional vehicle miles traveled (VMT) and reduces total fuel consumption and emissions levels.
- ***Traffic system effects***—In some cities, BRT has been shown to reduce congestion and improve overall traffic speeds, which can improve vehicle fuel economy and lower vehicle emissions.

Like other transit modes, BRT operations also can have noise or visual "pollution" impacts. These will primarily affect public health or well-being and the aesthetics of the surrounding community. BRT's noise and visual impacts are the result of the transit system's physical infrastructure—vehicles, running way, stations—as well as the treatments along the corridor. Experience with BRT indicates that these impacts can be positive or negative. Transit agencies will want to consider both the need to alleviate negative effects that may result from BRT operations and also how the system design can improve the auditory or visual environment.

This section reviews the current understanding of BRT's effect on five environmental quality indicators and explore the BRT system factors that have a significant impact on them. It considers only the impacts of BRT operations, not effects related to construction activities. Although transit construction may have significant environmental consequences, the effects are short-term. This section focuses upon the long-term environmental benefits that can help support a local community's decision to build a BRT system.

Definition of Environmental Quality

Environmental quality encompasses a broad array of issues. For this discussion, the focus is on five key environmental indicators:

- ***Local air pollutants*** have a significant, direct impact on the local environment and on public health. Transportation is the primary source of urban emissions of three local pollutants regulated by the U.S. Environmental Protection Agency: ground-level ozone, formed by a reaction between nitrogen oxides (NOx) and volatile organic compounds (VOCs), particulate matter (PM), and carbon monoxide (CO). This section will focus on BRT emissions of these three local pollutants.

- ***Greenhouse gases***—Transportation is the second biggest fossil fuel source of greenhouse gases (GHG), which can lead to global warming. Vehicle GHG emissions include carbon dioxide (CO2), methane, and nitrous oxide. CO2 is the dominant greenhouse gas, comprising more than two-thirds of total emissions in the U.S. However, methane is a concern because it has a much greater global warming impact than CO2. This section will review both greenhouse gases where possible, but CO2 data is typically more readily available from transit systems.

Currently, the U.S. EPA does not regulate vehicular GHGs. However, in April 2007, the U.S. Supreme Court ruled that the EPA does have the authority to regulate greenhouses gases, so it is possible that EPA will develop a GHG regulatory framework.

- ***Fuel economy*** relates to the BRT vehicles' fuel efficiency as well as the total fuel consumption of both BRT and passenger vehicles in the transit corridor. Fuel economy is of interest for promoting operational energy efficiencies and broader energy security. It should be noted that, while improved fuel economy may correlate positively with reduced emissions, this will not always be the case with certain fuel types. Fuel economy does correlate directly with CO2 emissions.

- ***Noise*** is becoming a greater environmental concern in neighborhoods with significant transit activity. In the context of BRT systems, this impact is defined as operational vehicle noise that results from the sound of the propulsion system and the vehicle tires on the running way.

- ***Visual impacts*** from transit operations are typically the result of physical infrastructure components as well as the treatments along the corridor.

Measures of Environmental Quality

Transportation environmental impacts can be difficult to quantify because they occur from a multitude of sources that are not easily measured. Environmental quality is affected by many more factors and within a large area, making it difficult to separate the impacts of a BRT system. In this report, the focus is on the following measurement mechanisms:

- For the first three indicators of environmental quality (local air pollutants, greenhouse gases, and fuel economy), general measures of emissions rates and fuel use of the elements used for a BRT system are proxies for specific measures in a specific corridor. To estimate BRT vehicle emissions, this section relies on federal transit bus engine emissions standards for CO, PM, and the two ozone forming pollutants, NOx and HCs. This section also uses measurements from laboratory testing of transit bus emissions and some limited real-world operational vehicle data collection. When possible, this section references emissions and fuel economy measurements from real-world data collection to estimate the overall impact of BRT. However, there has been very little data collection on BRT systems in operation. Transit agencies typically do not conduct such analyses, which are complex and expensive. This section also references the results of emissions modeling of potential BRT system impacts conducted by independent researchers and transit agencies for Environmental Impact assessments.

- For noise and visual impacts, the section relies upon anecdotal evidence and assessments of impacts. Generally, noise impacts or benefits are measured as levels of noise at specific points along a corridor. Visual impacts are assessed qualitatively as a positive or negative impact, also at specific points along a corridor.

Effects of BRT Elements on Environmental Quality

This section reviews how BRT system elements may impact each of five key environmental quality indicators for BRT. Vehicle emissions and fuel economy impacts are discussed together, since strategies to improve one of these factors will have a direct impact on the other.

Vehicle Emissions and Fuel Economy

Experience with BRT systems indicates that emissions and fuel economy improvements generated by BRT are the result of three related mechanisms: vehicle technology, ridership and mode shift, and traffic system effects. These are summarized in Exhibit 4-16 and described in detail below.

Vehicle Technology

BRT vehicles provide the most direct impact on environmental quality. Low emission or alternative propulsion systems and fuels, as part of a BRT system, have clear benefits for the environment in reduced pollutant emissions or improved energy efficiency. As a result of increasingly stringent engine emissions regulations and innovations in alternative fuel technologies, transit agencies can choose from many proven clean vehicle options for their BRT operations. (In the United States, these regulations include new fuel and propulsion system standards that went into effect in 2007 and 2010.) The most common clean fuel and propulsion system options are clean diesel, compressed natural gas (CNG), hybrid-electric, and biodiesel.

Exhibit 4-16: Emissions and Fuel Economy Improvement Mechanisms

Environmental Improvement Mechanism	Sources of Pollution Reduced	Objective	Significance of Impact
Vehicle Technology Effect	BRT vehicle emissions	Reduce direct BRT vehicle pollution by using: • larger (and fewer) vehicles • propulsion systems, fuels, and pollution control systems with reduced emissions	Moderate and immediate
Ridership / Mode Shift Effect	Auto emissions from private, low occupancy car trips replaced by transit	Reduce regional vehicle miles traveled (VMT) by attracting drivers to BRT through: • travel time savings • reliability • brand identity • safety and security • ease of use	High and indirect
System Effect	Local vehicle emissions resulting from traffic congestion	Reduce all vehicle emissions by: • reducing conflicts between BRT vehicles and other traffic • reducing overall system congestion • increasing overall vehicle speeds	Moderate/ high and indirect or immediate

✧ ***Diesel Buses***—Over the past several years, transit agencies have demonstrated the environmental benefits of "clean diesel": buses that employ engine controls and exhaust after-treatment devices and run on ultra low sulfur diesel (ULSD). These treatments significantly lower levels of emissions for particulate matter (PM), oxides of nitrogen (NOx), and sulfur dioxide. Two recent EPA regulatory actions will make clean diesel buses the industry norm. In October 2006, EPA regulations went into effect that require diesel to meet ultra-low sulfur emissions levels. Moreover, between 2007 and 2010, new engine standards will be phased in that will lower buses' PM emissions by 80 percent and NOx emissions by 90 percent from 2004 levels. The NOx emissions benefits from replacing very old buses will be even more dramatic.

  Transit agencies should be aware that these new emissions controls may reduce the buses' fuel efficiency. (While there are no current field data on this impact, this section does review projected fuel economy in the "2007 and Beyond" subsection.) It is also important to note that emissions control devices require maintenance to sustain their effectiveness. Overall, transit agencies that are currently planning BRT will demonstrate significant emissions reductions simply by replacing older buses with new buses for BRT operations.

✧ ***Biodiesel***—More transit agencies are using biodiesel fuel for their bus fleets, primarily for the PM and hydrocarbon emissions benefits. There are several available biodiesel formulations, but most transit agencies use a mixture with 20 percent biofuel called B20. A recent biodiesel emissions study indicated that B20 reduces PM by 20 percent and hydrocarbons emission by 15 percent. However, the study found that NOx emissions increased by about 3.3 percent (McCormick et al. 2006). Biodiesel also has lower fuel efficiency than conventional diesel. The U.S. Department of Energy estimates that biodiesel fuel economy is 1-2 percent lower than that of diesel fuel (National Renewable Energy Laboratory 2005).

Exhibit 4-17: U.S. EPA Emission Standards for Diesel Bus Engines (grams/bhp-hr)

Year	CO	HC(NMHC)	NOx	PM
1998	15.5	1.3	4.0	0.05
2004	15.5	0.5	2.0	0.05
2007 - 2010	15.5	0.14	0.20	0.01

- ***Compressed Natural Gas (CNG)***—CNG buses have been in revenue transit service for well over a decade, and their emissions benefits are well-established. They offer very low PM emissions, achieving the 2007 diesel PM levels since 2002. CNG buses also offer low NOx emissions. It should be noted, however, that the new diesel standards will reduce the differential between CNG and diesel bus emissions. CNG buses also provide an important energy security benefit, by diversifying the transportation sector's fuel sources.
- ***Diesel-Hybrid***—Since 1999, diesel-hybrids have moved from a demonstration technology to mainstream transit operations, with over 1,500 hybrid buses in service in the U.S. Because hybrid propulsion systems are not directly regulated by EPA, emissions and fuel economy estimates come from laboratory testing or operational data collection. In 2004, New York City Transit released results from its emissions tests on 40-ft hybrid buses, CNG buses, and diesel buses equipped with particulate traps. The tests showed that hybrids had the lowest NOx and CO emissions, while all three technologies had extremely low PM levels.

Exhibit 4-18: New York City Transit 40-ft Bus Emissions Comparison (gm/mi)

	CO	NOx	PM/10
Diesel with particulate filter	0.12	2.79	0.2
CNG	2.12	1.89	0.2
Orion VII hybrid	0.03	0.94	0.2

Source: New York City Transit SAE presentation, October 2004

Emissions and fuel economy testing on 60-ft articulated hybrid buses was conducted at King County Transit in Washington. The buses were tested on several duty cycles, including one that most closely reflects national average bus speeds (called the "OCTA" cycle). The results from this duty cycle showed that hybrids had lower PM, NOx, CO and CO2 emissions than a comparable diesel bus:

Exhibit 4-19: King County Transit 60-Ft Bus Emissions Comparison, on OCTA cycle

Emissions in grams per mile	CO	NOx	PM/10	CO2
Diesel	2.29	18.91	0.05	4579
Hybrid	1.55	13.50	0.24	3001

Source: NREL, December 2006

Transit agencies should be aware that while hybrid buses have been proven in transit operations, no data yet exist on the full 12-year life cycle performance and costs. In addition, some hybrid buses will require additional maintenance, depending on the battery technology used.

2007 and Beyond

It would be beneficial for agencies planning BRT to understand the expected in-use emissions and fuel economy benefits of their BRT fleet. However, there are no field data available on buses built to meet the new 2007 - 2010 regulations. In a July 2007 Federal Transit Administration study, researchers at West Virginia University estimated the potential emissions and fuel economy benefits

Exhibit 4-20: Emissions and Fuel Economy Estimates for 40-ft Buses, Year 2007 and Beyond (using OCTA cycle) (gm/mi)

	NOx	PM/10	GHG (CO2 & methane)	Fuel Economy (mpg)
Diesel	4.31	.021	2328	4.14
Diesel hybrid	4.41	.006	1972	4.90
B20 biodiesel	4.45	.017	2373	4.08
CNG	4.14	.010	2303	3.52

Source: FTA, "Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation," July 2007 of 40-ft buses that will be delivered in 2007 and beyond using current data adjusted to reflect the new engine standards. These estimates are also based on performance on the OCTA cycle. The results, shown below, reveal that all bus technologies are achieving very low emissions levels compared to older diesel buses while hybrids show the greatest fuel economy improvements and greenhouse gas reductions.

Ridership/mode shift: BRT can provide environmental benefits (reduce local pollutants, greenhouse gases, and fuel use) by diverting low-occupancy private car travel to high-capacity public transit vehicle travel. Shifting trips from private cars to BRT lowers regional vehicle miles traveled (VMT) and reduces total fuel consumption.

A 2002 International Energy Agency (IEA) study compared the relative impacts of mode shift and clean propulsion technologies in reducing emissions. The study assumed a bus load factor of 60, with 8 percent of the passengers having switched from private cars. At these high load levels, the IEA found that mode shift from private cars to public transit has a much greater environmental impact than use of clean vehicle technologies. The overall emissions reductions changed very little with the change in vehicle propulsion, even when the use of fuel cell buses was assumed.

More recently, the American Public Transportation Association (APTA) published a study on the contribution that public transportation makes to reducing U.S. greenhouse gas emissions. The study estimated that, in 2005, public transportation reduced U.S. CO2 emissions by 6.9 million metric tons. The study determined that, if all current public transportation riders were to use private vehicles instead of transit, they would generate 16.2 million metric tons of CO2. However, APTA calculated that actual operation of public transit vehicles resulted in only 12.3 million metric tons of CO2. The study also found that roughly 350 million gallons of gas were saved by reduced congestion due to public transit. However, it should be noted that this study is including all public transit CO2 emissions, and not only bus-related emissions. Therefore, it is difficult to extrapolate directly to the potential impacts of bus rapid transit.

Indeed, measuring the emissions and fuel use reductions from mode shift is complicated and costly. To quantify actual results, agencies must establish an extensive air quality monitoring system that calculates both baseline emissions levels and emissions after the transit system deployment. In lieu of field data collection, transit agencies use robust emissions models to predict the environmental impacts of VMT changes for proposed transit projects. These estimates are included in the Environmental Impact assessments required for all new transit construction projects.

Traffic System Improvements: In some cities, BRT has been shown to reduce congestion and improve overall traffic speeds, which can improve vehicle fuel economy and lower vehicle emissions. BRT may reduce regional transportation emissions by improving overall traffic flow and reducing conflicts between BRT vehicles and other traffic. However, quantifying this benefit is challenging. Measuring emissions changes due to improved traffic flow is difficult, as is creating a model to predict such impacts. However, there have been some efforts to quantify this impact:

- Some models have estimated the reduction of overall regional vehicular emissions from reduced congestion to be on the order of several percent (Darido 2000).
- A report on BRT in London found segregated running ways have been shown to decrease bus emissions by as much as 60 percent through more efficient speeds and fewer stops (Bayliss 1989).
- Preliminary studies of the CO2 reductions from Mexico City's BRT system found that as much as 46 percent of the reductions are the result of improved operating conditions for other vehicles (Instituto Nacional de Ecologia 2006).

Noise

As with all transit projects, agencies must consider the noise impacts of a BRT corridor on the local community. For BRT, the primary potential impact is noise and vibration from BRT vehicles. The level of vehicle noise is a function of the following system elements:

- propulsion system and configuration
- vehicle size
- frequency of service
- running way paving material

Certain propulsion systems are known to produce higher noise levels. This issue may be exacerbated by the larger engines needed to power articulated buses often used in high capacity BRT systems. Diesel buses will produce the most noise pollution. A hybrid-diesel bus is quieter because it uses a smaller diesel engine and relies on a quiet electric motor for some of its power. CNG buses are also typically quieter than diesel buses, depending on the level of maintenance of the propulsion systems; however, some articulated CNG buses have demonstrated increased vibration.

BRT service designs typically feature shorter headways than conventional bus service. This may create noise issues due to very frequent bus travel along the transit corridor. The noise impacts result from both the engine noise and the sound of the tires on the running way. To mitigate this problem, transit agencies may need to consider using lower-noise bus technologies, noise-reducing running way materials, or soundwalls. There also has been some interest in new running way materials designed to mitigate tire noise, such as "rubberized asphalt." However, these are still relatively new technologies, and it is not yet proven that they provide a significant noise mitigation impact. In addition, transit agencies will need to develop specifications to ensure the long-term durability of such specialized asphalt or pavement.

Visual Impacts

BRT's major physical infrastructure elements—the running way, vehicles, and stations—may have visual impacts which should be understood by system planners. In addition, because BRT infrastructure costs are typically relatively low, some transit agencies have been able to invest in major landscaping or streetscape improvements along the BRT corridor, providing both an aesthetic benefit and enhanced livability for the neighboring community.

Some ways that BRT systems affect the visual environment include:

- ***Vehicle impacts***—BRT vehicles do not require overhead wires, eliminating one potential element of "visual pollution."
- ***Station impacts***—Stations relate to surrounding communities and create new structures that should be in harmony with the surrounding landscape.
- ***Running way impacts***—BRT systems can include major landscaping and other aesthetic improvements along the BRT corridor. It is also possible to incorporate landscaping effects within the BRT running way itself to enhance its visual appeal.
- Some transit agencies incorporate bike and walking paths along BRT running ways, enhancing overall livability.
- The need for soundwalls to protect adjacent neighborhoods from BRT vehicle noise can detract from the look of the running way.

Other Factors Affecting Environmental Quality

There are additional environmental impacts from transit systems that are not evaluated in this report that may have an impact on public health and air quality. These include:

- ***Unregulated Air Toxics***: In recent years, public officials have become aware of significant health problems caused by previously unregulated air toxics. As a result, EPA has been developing a regulatory framework for these emissions; however, there has not yet been a rule promulgated for transit bus engines.
- ***Sulfur Dioxide***: While diesel-burning buses emit sulfur dioxide, which causes acid rain, most emissions are from stationary sources such as power plants. In addition, diesel buses' sulfur emissions will be significantly reduced due to EPA's ULSD standard, which went into effect nationwide in 2006. By 2010, all highway diesel fuel must be ULSD.
- ***Solid and Liquid Wastes***: All transit operations will generate some solid and liquid waste products. While transit agencies should seek to limit these products by using sustainable practices, this issue is not unique to BRT and is not covered in this document.

In addition, there are many factors that affect the level of environmental benefit provided by a transit system that are beyond the control of the agency. Some of these factors are:

- emissions standards of private cars and other private transport
- emissions standards of freight, air and water transport
- levels of commercial vehicle traffic
- policies that may encourage public transportation over private vehicle use, such as parking restrictions, HOT lanes, funding apportionments for road building vs. public transportation infrastructure, etc.

- corridor restrictions that limit the ability to implement landscaping and other aesthetic improvements

Finally, it is important to acknowledge that there are many other activities in a region that affect environmental quality. The location and types of industries and commercial activities, the organization of land development patterns, and local climatic conditions all affect environmental quality. All of these factors cannot be controlled by an individual transit agency or even a municipal jurisdiction.

Summary of Impacts on Environmental Quality

This section summarizes the state of research on BRT systems' impact on each of the environmental quality factors.

Criteria Pollutants

Transit agencies in the United States typically do not conduct a system-wide emissions impact analysis once a transit service is in operation. Consequently, there are no studies quantifying the effect on local or regional criteria pollutant levels of BRT systems in the United States. Transit agencies are required to estimate the potential emissions impact of new transit service in Environmental Impact Assessments and, until recently, the New Starts funding process. A review of recent and planned BRT projects' environmental analyses showed that BRT does provide a long-term emissions benefit, although the total reduction is small. On average, the BRT projects reduced vehicle emissions of CO, NOx, VOCs, and PM by less than one percent over No Build or Transportation System Management (TSM) alternatives. These levels are comparable to the emissions projections of other rapid transit projects.

One of the few BRT systems to analyze emissions impacts using actual service data, Mexico City's Metrobús, provides valuable documentation of a BRT's positive impact on local criteria pollutants and greenhouse gases, as well as insight into the factors contributing to these reductions. Details are discussed in the section on System Performance Profiles.

Greenhouse Gas Emissions

Limited research exists that analyzes the potential impact of bus rapid transit on greenhouse gas emissions. However, some recent research suggests that BRT can have a positive effect:

- A 2005 *Journal of Public Transportation* article found that BRT using low emission vehicles such as compressed natural gas or hybrid-diesel would reduce overall vehicle-related greenhouse gas emissions (Vincent and Jerram 2005). The study attributed the reductions to use of low emission vehicle technology, passenger loads comparable to light rail, and mode shift from private car travel to the BRT.

- A 2005 FTA report also predicted significant reductions in vehicular CO2 emissions by replacing private vehicle travel with BRT. The FTA study adapted a model developed by the American Public Transportation Association designed to quantify the impact of public transit on vehicle emissions and energy use. The FTA version of the model calculates the emissions that would result if BRT passenger miles replaced private vehicle travel. The model predicted that a 40-mile BRT corridor, based on the Los Angeles Metro Rapid design, provides a 70 to 74 percent reduction in annual CO2 emissions, depending on the BRT vehicle fuel.

- A 2005 study by Wright and Fulton examined the effect of mode-shifting scenarios on CO2 emissions for developing countries. The study predicts that the largest and most cost effective emissions reductions would come from implementing BRT systems with pedestrian and cycling improvements to reduce the level of private car travel. This was more effective than implementing clean bus technologies or implementing BRT without additional improvements.

As with criteria pollutants, there is little documentation of the impact BRT systems have had on GHG emissions. The best analysis has been completed by Bogotá to qualify the Transmilenio BRT for carbon trading credits. This effort is described in the section on System Performance Profiles.

Noise and Visual Impacts

There are no systematic evaluations of noise from BRT systems, so the primary evidence for any noise impacts is anecdotal. The same is true for visual impacts, which cannot be measured in any systematic manner. See the section on System Performance Profiles for anecdotal experiences of BRT's noise and visual impacts.

System Performance Profiles

Mexico City

Mexico City has more than 20 million inhabitants, who make over 30 million vehicular trips each day. Between 70 and 80 percent of all daily person trips are by public transport, including 4.5 million trips on the subway. There are roughly 28,000 bus concessions in the city, about 70 percent of which are microbuses.

In 2005, the city opened the BRT service Metrobús on Avenida de los Insurgentes, an 18-mile avenue in the heart of Mexico City. Metrobús serves 12 miles of Insurgentes with 97 new articulated diesel BRT vehicles.

A March 2006 study (Instituto Nacional de Ecologia 2006) analyzed the greenhouse gas time savings impact of Metrobús since it began operating in June 2005. Using data on vehicle activity and speeds collected during Metrobús service, the study calculated BRT vehicle emissions and estimated the emissions that would have occurred from the trips replaced by the BRT. The authors then developed an emissions impact projection for 2005 to 2010, with the BRT reducing all pollutants, as shown below:

Exhibit 4-21: Emissions Impact of Metrobus Vehicles vs. Trips Replaced

Pollutant	Reduction in 2006	Average annual reduction, 2005 - 2010
Total hydrocarbons	194 metric tons	144 metric tons
NOx	824 metric tons	690 metric tons
$PM_{2.5}$	4.4 metric tons	2.8 metric tons

The study estimated that the health benefits of reduced criteria pollutant emissions were worth approximately $3 million per year from 2006 to 2010.

Mexico City is also working on a methodology to qualify for credits under the Kyoto Protocol's Clean Development Mechanism (CDM). The methodology is in development, but Metrobús operational data collected for the CDM model was used in the March 2006 study to estimate CO2 emissions impacts. The study authors estimate that, from 2005 to 2015, the Metrobús corridor will eliminate 280,000 tons of CO2-equivalent emissions.

Bogotá

Bogotá has roughly seven million inhabitants, and more than half of its daily trips are on public transportation. Transmilenio is a 25.6-mile BRT system (with feeder buses) that uses 160-passenger, biarticulated diesel buses to carry 1.3 million passengers per average weekday. Prior to Transmilenio, public transportation in Bogotá was provided almost exclusively by private buses.

Transmilenio is the first transit system to be certified for greenhouse gas emission credits under the Kyoto Protocol's CDM. The CDM helps developing countries finance sustainable development by allowing them to sell credits for reductions in GHG on a carbon trading market. Transmilenio's GHG benefits were calculated after an extensive data collection effort and construction of a methodology that can be used by other developing countries to quantify the GHG impact of BRT. According to the CDM methodology, the Transmilenio reduces nearly 250,000 tons of CO2 equivalent gases per year.

The 2007 BRT Planning Guide published by the Institute for Transportation and Development Policy (ITDP) examined the impact of TransMilenio emissions within the Bogotá region. They found that one of the important mechanisms for achieving these results was the mode shift from private cars to public transit that resulted from the dramatic improvements in transit service quality provided by the BRT (i.e., travel time, comfort, security, cleanliness) (Institute for Transportation and Development Policy 2007).

Lane Transit District EmX Green Line

The Lane Transit District (LTD) conceived its BRT service, the EmX, as a "green" system. The EmX Green Line serves Eugene and Springfield, Oregon. The "green" design elements are an important part of the system branding, meant to complement the area's natural environment. Some of the environmental elements are:

- a hybrid-electric bus fleet
- a grass median strip along portions of the busway, which enhances the visual appeal of the paved busway and absorbs oil discharge from the bus
- extensive landscaping with native plants along the corridor and at stations
- a new Springfield bus terminal built to meet national "green building" standards

Los Angeles Orange Line

The Los Angeles Orange Line BRT offers several examples of potential noise and visual impacts from BRT. After the launch of the Orange Line in 2005, Metro received complaints from neighbors along the busway about noise from the 60-ft CNG buses, which ran at 7- to 12-minute peak headways. Metro responded by redirecting the CNG vehicles' exhaust pipes to vent away from the residences alongside the running way. The agency also installed soundwalls along portions of the busway.

Los Angeles is the only U.S. BRT system to experiment with a new noise reduction strategy: paving portions of the Orange Line busway with rubberized asphalt designed to minimize tire noise. However, the rubberized asphalt significantly deteriorated after only one year of operation and was replaced with conventional pavement. As of the writing of this report, the LA transit agency was working to definitively determine the cause of this problem (Callaghan and Vincent 2007).

The Orange Line is also a good example of using landscaping along the BRT corridor to provide environmental improvements. The Orange Line corridor features 77 acres of landscaping with over 800,000 plantings and an irrigation system. Metro selected native plants that could tolerate drought conditions to minimize water use (Woodbury 2007).

BRT Elements by System and Environmental Quality

The following section provides available data from worldwide BRT systems on the use of clean vehicles and the ability to impact mode share.

Mode Shift

The results for BRT systems are mixed, but data from operating BRTs demonstrates that BRT can induce mode shift from private cars to transit:

Exhibit 4-22: Percentage of BRT Riders Shifted from Private Motor Vehicles

BRT Corridor	Percent of Ridership From Private Motor Vehicles
Albuquerque Rapid Ride	33%
Boston Silver Line Washington Street	2%
Boston Silver Line Airport	19.6%
Boston Silver Line BMIP	49.5%
Las Vegas MAX	10%
Los Angeles Orange Line	33%
Oakland San Pablo Rapid	19%
Halifax MetroLink (all line)	23-28%

This ability of BRT to shift trips from private automobiles to transit is analyzed at greater length in Section 4.1.4 on BRT's ridership impacts.

Clean Vehicle Use

In the United States, the transit industry is moving toward greater use of alternative propulsion systems and fuels to reduce emissions and improve fuel economy. A high percentage of BRT systems have been deploying alternative propulsion buses, with over half of those opened since 2004 using either CNG or hybrid vehicles. In August 2008, WestStart-Calstart published a Vehicle Demand Analysis. This report surveyed U.S. transit agencies that are planning or building BRT services. The report's preliminary findings indicate that U.S. transit agencies are increasingly interested in using alternative fuel vehicles such as hybrid-electric, CNG, and biodiesel for their BRT systems. The study found that, of 63 communities planning some form of BRT service between 2007 and 2017, a majority were planning to implement an alternative fuel technology. Hybrids were the most popular alternative fuel option, with 40 percent of the communities planning or using hybrid buses; 31 percent were committed to CNG, and 12 percent were using biodiesel. This tendency is even more pronounced among communities planning full-featured BRT. WestStart surveyed 20 communities planning or building a full-featured BRT system and found that 12 were committed to deploying hybrid technology, four were committed to CNG, and one planned on using biodiesel (Weststart-CALSTART 2008).

The use of alternative fuels is much less common outside the U.S. Of the systems that provided data for this report, there were only four that used vehicles powered by alternative fuels: Halifax, which uses biodiesel for its Metrolink BRT; Eindhoven, which used an LPG-electric hybrid; Caen, which uses dual-mode vehicles; and Brisbane, which uses both diesel and CNG buses.

Exhibit 4-23: Summary of U.S. BRT System Vehicle Propulsion Technologies

BRT System	Vehicle Configuration	Propulsion System and Fuel
Albuquerque Rapid Ride	Articulated	Hybrid diesel electric, ULSD
Boston Silver Line Washington Street	Stylized articulated	CNG
Boston Silver Line Waterfront	Stylized articulated	Dual-mode diesel and electric, ULSD
Chicago Neighborhood Express	Conventional standard	Diesel, ULSD
Cleveland Health Line (opens 2008)	Stylized articulated	Hybrid diesel electric
Eugene EmX Green Line	Stylized Articulated	Hybrid Diesel Electric
Foothill Transit Silver Streak	Stylized Articulated	Hybrid Diesel Electric
Kansas City MAX	Stylized 40’	Clean diesel
Las Vegas MAX	Stylized articulated	Hybrid diesel electric
Los Angeles Metro Rapid	Stylized standard and articulated	CNG
Los Angeles Orange Line	Stylized articulated	CNG
Miami Busway	Conventional standard and articulated	Diesel, CNG, hybrid
Oakland San Pablo Rapid Bus	Stylized 40’	Diesel
Orlando LYMMO	Standard	Diesel, ULSD
Phoenix RAPID	Specialized standard	LNG
Pittsburgh Busways	Conventional Standard and articulated	Diesel
Santa Clara VTA Rapid 522	Stylized standard and articulated	Diesel, ULSD
Sacramento Ebus	Standard 40’	CNG

CONCLUSIONS AND SUMMARY

The preceding chapters of this report encapsulate the experience with BRT. Chapter 2 presented a summary of the primary physical, operational, and cost characteristics of BRT, organized by the six major elements of BRT: Running Ways, Stations, Vehicles, Fare Collection, ITS, and the Service and Operations Plan. Chapter 3 highlighted the attributes of performance affected by the BRT system elements: Travel Time, Reliability, Image and Identity, Passenger Safety and Security, System Capacity, and Accessibility. Chapter 4 discussed the major benefits that BRT systems affect: High Ridership, Capital Cost Effectiveness, Operating Cost Efficiency, Transit Supportive Land Development, and Environmental Quality. Each of these chapters included illustrations of specific BRT experience and summaries of BRT systems in the United States and around the world. This presentation of the BRT experience along three dimensions is intended to allow the reader to glean insights about BRT from any perspective.

This chapter concludes the report in two major ways. First, it provides an overview of BRT experience as presented in the core of the report. Second, it describes the role of the report as a living and dynamic document, intended to reflect the evolving knowledge base related to BRT.

SUMMARY OF BRT EXPERIENCE

Summary of BRT Elements

Experience in the United States suggests that implementation of more complex BRT system elements is just beginning. Implementation of running ways, stations, and vehicles suggests a wide variety of applications. Some of the more quickly implemented projects demonstrated the least amount of investment in BRT system elements.

Running Ways

BRT systems in North America incorporate all types of running ways—mixed flow arterial operation (Los Angeles, York), mixed flow freeway operation (Phoenix), dedicated arterial lanes (Boston, Orlando), at-grade transitways (Cleveland, Eugene, Los Angeles, Miami), fully grade-separated surface transitways (Pittsburgh, Ottawa), and transitways with some underground operation (Boston). Overall, use of on-street running ways, either mixed-flow or dedicated, continues to dominate BRT in the United States. However, there have been more dedicated guideway BRT projects since 2004—both median on-street busways built in Eugene and Cleveland and the dedicated busway built in Los Angeles. In Europe, Australia, Latin America, and China, most BRT systems do not operate in mixed-flow lanes, and completely grade-separated busways are common. Use of running way guidance is most common in Europe; few BRT systems elsewhere utilize either optical or mechanical guidance systems. The only recent BRT system in the U.S. to implement mechanical guidance is Cleveland. In the United States, the use of unique running way markings to differentiate BRT running ways has become more common, with signage and striping the most common markings employed. Some systems, such as the Eugene EmX, use different-colored pavement, both to differentiate the busway from mixed-flow lanes and to articulate a distinct brand identity.

Stations

There has been a broad range of sophistication and design attention in BRT stations. Almost universally, BRT station designs are significantly different than those of standard local bus stops; the level of investment in the stations has generally been related to the level of investment in running way infrastructure. Exclusive transitways are most often paired with the most extensive and elaborate station infrastructure. With more BRT systems in the United States implementing dedicated busways (although these are still in the minority), there is also greater investment in stations. The station design also suggests that they are considered an important part of the system branding identity and, in some cases, are being designed to integrate effectively into the surrounding streetscape. Most of these are still simply enhanced stations, not station buildings, although the MBTA built two underground stations for the Silver Line Waterfront BRT in Boston. It is mainly outside the U.S. where cities build substantial enclosed station structures similar to those found in rail lines. Cities such as Brisbane, Bogotá, Guayaquil, and Pereira have made significant investments in BRT station infrastructure.

Level boarding is common in Latin American and European systems. Curitiba, Brazil and Bogotá, Colombia have the most noteworthy and early level boarding systems. Many European cites use some type of lateral guidance treatment, as noted below in the ITS Summary. In the United States, Canada, and Australia, few BRT systems have true level boarding (the Cleveland HealthLine and Las Vegas MAX are among the few), although some do have raised platforms (Los Angeles Orange Line) or near-level boarding (Eugene EmX). As would be expected, passing capability and multiple vehicle berths at station platforms are directly correlated with degree of running way separation. Systems with off-street guideways, such as Miami, Los Angeles, Ottawa, Pittsburgh, and several Australian BRT systems, provide additional lanes for passing and longer platforms for multiple vehicle berthing. On-street running ways typically do not allow several vehicles to stop at one time and use bus pullouts rather than passing lanes due to right-of-way constraints.

The mix of station amenities varies across systems. The most common station amenities focus on passenger comfort with seating, lighting, and trash receptacles. Many systems are incorporating real-time schedule and/or vehicle arrival information, as is noted in the ITS Summary below. Other communications infrastructure such as public telephones and emergency telephones are starting to be installed in systems.

Most BRT systems around the world have intermodal transfer facilities where there are specially-designed interfaces with other bus services and rail rapid transit systems. In the United States, stations with park-and-ride facilities are generally part of systems with exclusive transitways (e.g., Miami-Dade South Busway, Pittsburgh busways, Los Angeles Orange Line) or where the BRT connects to a rail station (San Jose Rapid). Park-and-ride stations are less common outside the U.S. but still are found in some BRT systems, especially in Australia.

Vehicles

Distinct vehicles are a very common element in United States BRT systems, while their use in the rest of the world varies. In the United States, almost all BRT systems use vehicles with a distinct livery, at a minimum, and many use vehicles with specialized exterior styling and interior amenities such as more comfortable seating, higher quality materials and finishes, and better lighting. It is also very common for United States BRT vehicles to use alternative propulsion systems, primarily CNG or diesel-hybrid.

A mix of standard and articulated vehicles reflects the different levels of demand and capacity requirements across all BRT systems. In the United States, a majority of BRT systems have at least some articulated vehicles in the fleet, with several served exclusively by articulated buses. However, use of articulated vehicles is much more common in systems that require very high capacities, such as those in Latin America, several in Europe, and China. An exception is the Brisbane busway system, which reaches very high capacities while using standard buses.

Distinct vehicle styling is a strong component in the Latin American and European systems but is not utilized in the Australian systems. Alternative propulsion systems are significantly less common outside the United States, with most using diesel powertrains.

Fare Collection

Most United States BRT systems continue to use on-board fare payment systems. However, a few systems have implemented alternate fare collection processes in an effort to reduce dwell times. Because U.S. systems typically do not feature enclosed stations, the most commonly-used off-board method is either a proof-of-payment system or use of transit passes. By contrast, Latin American BRT systems have enclosed stations that allow them to use barrier-enforced off-board payment. The European and Canadian systems typically use on-board or proof-of-payment methods, while the Australian BRT systems all utilize pay-on-board fare collection.

Electronic fare collection using magnetic-stripe cards or smart cards is slowly being incorporated into BRT systems, but implementation is largely driven by agency-wide implementation rather than BRT-specific implementation. Smart cards are gaining wider application than magnetic-stripe cards among BRT systems.

ITS

The most commonly-deployed ITS applications are Operations Management Systems, especially Automatic Vehicle Location, and Transit Signal Priority, which is especially common for cities seeking to improve travel times without building dedicated guideways. Real-time traveler information at stations and on vehicles is becoming increasingly common. Installation of security systems such as emergency telephones at stations and closed-circuit video monitoring is becoming much more common in the United States, but less so in other worldwide BRT systems. Use of Intelligent Vehicle Systems such as precision docking, lateral guidance, or collision avoidance is rare, although, as already noted, some European BRT systems frequently employ some method of precision docking.

Service and Operating Plans

In general, the structure of routes and type of service correlates with the degree of running way exclusivity. Since most U.S. BRT systems operate on-street, there is less opportunity for them to incorporate a variety of service routes; most use single, all-stop routes. The two notable exceptions are Miami-Dade's at-grade South Busway and Pittsburgh's grade-separated transitways, which operate with integrated networks that include routes that serve all stops and a variety of feeders and express routes with integrated off-line and line-haul operation. This is the type of BRT network plan used for the Latin American BRT systems, the Ottawa Transitway, and the Brisbane busways. These systems have integrated their citywide bus service to feed into the busways and accommodate multiple routes offering all-stop, limited-stop, and express service.

Service hours and frequencies correlate with demand and degree of running way segregation in the respective corridors; however, most BRT systems offer all-day service and peak-hour frequencies of 12 minutes or less. Typically, BRT systems on arterials operate with headways between 5 and 15 minutes. Services operating on exclusive running ways have much higher frequencies, with at-grade running ways typically showing 4- to 10-minute headways, while grade-separated running way frequencies typically have headways less than 5 minutes.

Station spacing generally falls between one-half to one mile. A few BRT systems do show closer station spacing, down to as little as one-quarter mile, which is comparable to local bus service. Most, however, achieve one-half-mile spacing at a minimum, with a few of the express services showing even longer station spacing.

Branding Elements

Experience shows that it is more common than not for BRT systems to be marketed with some differentiation, most often as a separate tier of service—either as a service differentiated from local lines or as an entire package of BRT elements, such as the transitways in Miami, Ottawa, and Brisbane. Some locations, such as Boston and Los Angeles, do market BRT lines (the Silver Line and Orange Line, respectively) as part of the regional rapid transit system, equating the BRT lines with rail lines.

Use of branding devices is also very common. When BRT elements are implemented systemwide, some differentiation with a brand name is most often employed. Especially in newer systems, logos and designated colors are often applied. Use of designated colors is often used where the goal is to differentiate from local service and the service plan is of a single line nature, rather than an integrated network (with trunk and branches). This is true in mixed-flow BRT systems, such as the Metro Rapid in Los Angeles and the Rapid systems in Oakland and Phoenix. This is also true with newer systems such as the EmX in Eugene and the HealthLine in Cleveland.

Summary of BRT Performance

Travel Time

Overall, BRT systems are reporting improvements in travel time over previous corridor travel times or existing local bus service. Improvements range from 5 to 70 percent, with the median percentage improvement at 25 percent, due mainly to the large number of on-street running way BRTs in the U.S. The strongest indicator of improved travel time is the level of running way segregation, and most systems with less than 25 percent improvement operate on-street in mixed traffic lanes. The systems with the highest reported travel time savings of 40 percent or higher were those with grade-separated busways. One notable exception is busways with at-grade intersections, which can require slower bus speeds due to safety concerns. Few BRT systems provided any data on performance relating to other travel time indicators such as dwell time or wait and transfer time. Dwell time, in particular, would be a valuable measurement since BRT systems are increasingly investing in fare collection, level boarding, and multiple-door vehicles—features intended to reduce dwell time.

Reliability

The key reliability performance indicator for BRT systems is Ratio of Maximum Time to Unconstrained Time, determined by dividing the peak-hour end-to-end travel time by the non-peak end-to-end travel time. A ratio higher than 1:00 indicates that peak travel times are longer than non-peak, and the higher the ratio, the more variable the travel time.

Not surprisingly, the ratio is typically lower for BRT systems that operate along dedicated or exclusive lanes than for those systems that operate within a mixed-flow environment. Of the systems that provided data for this report, almost all that operate on a segregated running way have a ratio of 1.0 to 1.2. For systems that operate along mixed-flow lanes, this ratio was typically higher, particularly in regions suffering from heavy local traffic conditions. Unlike with travel times, segregated running ways with at-grade intersection crossings do not appear to suffer a performance penalty for reliability.

Image and Identity

Only a few BRT systems report having conducted in-depth passenger surveys to measure performance in achieving a distinct brand identity. However, results of several customer satisfaction surveys have been good. For example, passengers on the Los Angeles Orange Line rated the MetroLiner vehicles highly; 79 percent of riders on Oakland's San Pablo Rapid rated the vehicle look as good or very good, while 90 percent rated ease of identifying service as good or very good. Other customer service surveys in Los Angeles, Kansas City, and Las Vegas have reported very high customer satisfaction ratings.

In the United States, there is a very strong interest in the branding element of BRT, with vehicles the most commonly-used feature to convey a distinct, high-quality image. Vehicles are also a strong branding element in Europe and Latin America. Other systems, such as Brisbane and Ottawa, rely on the fully grade-separated running way to convey the BRT brand and utilize conventional vehicles.

Safety and Security

Very few systems have reported any safety data, on either vehicle or passenger safety, so it is not possible to draw any statistically-significant relationships between elements and performance. A few have reported both positive and negative results. Pittsburgh reported fewer bus accidents on the East Busway corridor once the Busway was opened, not surprising since the East Busway is fully grade-separated. Many systems with off-street busways operate with at-grade intersection crossings, a feature that has been identified with increased accidents between buses and other vehicle traffic or pedestrians. For example, the Los Angeles Orange Line had several incidents shortly after the at-grade busway opened. However, recent performance data provided by Metro show that the Orange Line has a much lower accident rate per mile than the Metro Rapid service, which operates in mixed traffic. This suggests that greater opportunities for accidents occur with buses operating in mixed traffic than in at-grade busways. With limited data reported on safety, however, it is not possible to draw any definitive conclusions.

Capacity

The primary capacity performance measure provided for this report is Maximum Critical Link Throughput data. The data on this measurement support the theory that vehicle capacity, station capacity, and running way capacity are the primary elements impacting total person capacity for a BRT system. The other element that strongly correlates with maximum throughput is frequency of service. Maximum capacity appears to result from a combination of these elements, rather than any one element being the dominant determinant. In general, as systems add more intensive elements and more investment, this is reflected in increased capacity.

The BRT systems with the lowest capacity levels are typically those with on-street operations (the most common running way type in the U.S.), less substantial stations, and standard size vehicles. These systems typically have maximum capacities from 200 to 400 passengers per direction per hour since they reflect the low number of peak hours buses operated. Systems that can accommodate 600 to 850 passengers per direction per hour typically feature more intensive elements. The systems that reported passenger capacities between 1,000 and 1,264 passengers per direction per hour operate primarily in exclusive busways, most located off-street and typically with higher capacity stations; some, but not all, use articulated vehicles. The five systems that reported passenger capacities between 2,400 and 5,000 passengers per direction per hour operate on off-street busways with articulated vehicles. The systems in the world with the highest reported capacity are Kunming's BRT network, Brisbane's South East Busway, and Bogotá's Transmilenio, with capacities of 15,000 to 45,000 passengers per direction per hour. These are all BRT networks or services that accommodate multiple lines and operate off-street with very substantial stations and extremely high frequencies.

Accessibility

Data on accessibility performance for BRT systems are not as readily available. BRT systems are implementing features intended to improve accessibility for all passengers, such as low-floor buses, near-level or level-boarding, and vehicle stop announcements.

Summary of BRT System Benefit Experience

Ridership

There have been increases in transit ridership in virtually all corridors where BRT has been implemented. Increases in BRT ridership have come from both individuals that used to use transit and totally new transit users that have access to automobiles.

Data on BRT systems around the world reveal a wide range of ridership increases, from as little as 5 percent to well over 100 percent. Typically, increases are at least around 35 percent, and many are significantly higher. However, it is difficult to compare the reported results from various systems, since some systems are reporting ridership numbers after years of operation, others only months. The data confirm the connection between ridership totals and the type of running way, vehicle, and station elements deployed and service frequency. The ridership figures also confirm that all types of BRT systems can attract ridership and that BRT can accommodate extremely high transit demand. The data also reveal that some BRT systems can divert trips from private car to transit.

Aggregate analyses of ridership survey results continue to suggest two conclusions:

- The ridership impact of BRT implementation has been comparable to that experienced with LRT investment of similar scope and complexity.
- The ridership increases due to BRT implementation tend to exceed those that would be expected as the result of simple level of service improvements. The implication here is that the identity and passenger information advantages of BRT are seen positively by potential BRT customers when they make their travel decisions.

Capital Cost Effectiveness

BRT demonstrates relatively low capital costs per mile of investment. It is worth noting, however, that several recently-implemented BRT systems have focused more capital-intensive investments. Depending on the operating environment, BRT systems are able to achieve service quality improvements (such as travel time savings of 15 to 25 percent and increases in reliability) and ridership gains that compare favorably to the capital costs and the short amount of time to implement BRT systems. Furthermore, BRT systems are able to operate with lower ratios of vehicles compared to total passengers because of their greater passenger capacity.

Operating Cost Efficiency

BRT systems are able to introduce higher operating efficiency and service productivity into transit systems that incorporate them. Experience shows that when BRT is introduced into corridors and passengers are allowed to choose BRT service, corridor performance indicators (such as passengers per revenue hour, subsidy per passenger mile, and subsidy per passenger) improve. Furthermore, travel time savings and higher reliability enable transit agencies to operate more vehicle miles of service from each vehicle hour operated.

Transit-Supportive Land Development

In places where there has been significant investment in transit infrastructure and related streetscape improvements, there have been significant positive development effects. Examples of these include Cleveland, Boston, Brisbane, Pittsburgh, and Ottawa. In some cases, the development has been located adjacent to the transit facility, while in other places the development has been integrated with the transit stations. Although there are very good early indications of BRT systems that can attract TOD, experience is not yet widespread enough to draw definitive conclusions on the factors that would result in even greater development benefits from BRT investment. Generally, the factors that do contribute to more development around BRT are the same as those factors that contribute to more development around rail modes: conducive market conditions and land use policies. More research on this topic is under way; early indications are that a significant level of infrastructure investment can improve surrounding streetscapes and provide assurances of the permanence of the BRT. However, other BRT lines with minimal running infrastructure—such as the York Region's VIVA—are seeing adjacent development activity as well.

Environmental Quality

Documentation of the environmental impacts of BRT systems is limited. Experience shows that there is improvement to environmental quality due to a number of factors. Ridership gains suggest that some former automobile users are using transit as a result of BRT implementation. Transit agencies are serving greater passengers with fewer hours of operation, potentially reducing emissions. Most importantly, transit agencies are adopting vehicles with alternative fuels, propulsion systems, and pollutant emissions controls.

SUSTAINING THE CBRT REPORT

The CBRT report presents a useful compendium of information for supporting BRT planning, design, and operations. This 2008 edition presents a snapshot of the collective experience of BRT. Since 2004, the experience with BRT has grown, and this version of CBRT has added more useful cases for study. To enhance the usefulness of this report as a key BRT information source, information from additional experience with BRT systems and lessons learned from their implementation and operation have been incorporated. Sustained usefulness of the report relies on future updates that incorporate even more experience with future BRT applications and ongoing research and development activities.

Supplemental Evaluation of Operating BRT Projects

"Characteristics of BRT" builds upon a tradition of research on the implementation of BRT elements and BRT projects. FTA has completed evaluation efforts for at least seven BRT projects: Pittsburgh (Martin Luther King Jr. Busway and West Busway), Miami, Orlando, Boston, Oakland, Honolulu, and Las Vegas. Project implementation agencies continue their own ongoing individual evaluation efforts. Future editions of this report can continue to incorporate information from new and updated evaluations of operational systems.

Several new topics should get updated reviews, including safety and security, accessibility, land use, and environmental benefits. Furthermore, more detailed measurements of certain performance measures, such as reliability and customer satisfaction, can provide a more thorough and qualitative understanding of how BRT elements contribute to them.

Evaluation of New BRT Projects

BRT projects currently in development can provide additional sources of information. At least four major BRT projects in the United States began operation between 2004 and 2008—Orange Line (Los Angeles), EmX (Emerald Express—Eugene), HealthLine (Euclid Corridor, Cleveland) and Select Bus Service (Fordham Road in New York City corridor). In addition, the Hartford-New Britain Busway (Hartford, Connecticut) is on track to be in operation by 2012. These projects provide new quantitative data and more complete information on the impact of some BRT elements, such as exclusive transitways, proof-of-payment fare collection, and precision docking systems. Furthermore, they can provide useful project history on how to address issues such as sharing single-lane guideway sections, operation adjacent to an active railroad, safety at crossings, and operation of vehicles with doors on both sides of a vehicle.

Incorporating International Experience

The international community implementing BRT is growing and increasingly is exchanging information to learn from each other. This report incorporates data on BRT systems from Canada, Colombia, Europe, Australia, and China through specific data collection efforts. Additional data collection is necessary to build a broader database from existing systems in other locations. Data from several cities in Brazil, long the pioneer in the development of BRT systems, especially one of the original BRT systems in Curitiba, and other locations throughout Latin America, Europe, and Asia will create a more complete picture of the broad applications of BRT. Furthermore, new systems are being developed in Africa, Southeast Asia, and India. Cases from the more developed systems and newer systems may provide useful lessons.

Compiling Ongoing Information on Performance and Benefits

To draw more definitive conclusions about the implementation of BRT, it is often important to have a large set of data on several systems over a period of several years. While other modes benefit from longstanding efforts for collecting and reporting data, such as the National Transit Database (NTD), a common platform or methodology for collecting and reporting BRT system data has yet to be developed. This report represents an attempt to report on BRT experience (major project elements, performance, and benefits) in a single, unified format. This edition has attempted to standardize the set of data that are collected. Future updates can benefit from updates to this data set emphasizing three principles:

- ***Consistency***—data collected consistently, with common definitions and common units of measurement allow for effective comparison across projects
- ***Regularity***—data collected at regular intervals, allowing for a characterization of how BRT systems and their performance evolve over time
- ***Simplicity***—data collected regularly, requiring that the methods to collect it be simple and easy to understand

Incorporating General Transit Research

This report has drawn heavily upon general research and syntheses of experience in transit, including several documents produced by industry groups such as the American Public Transportation Association (APTA) and programs such as the Transit Cooperative Research Program (TCRP). The work conducted under the auspices of TCRP Project A-23 and A-23A (TCRP 118) has advanced research on BRT even further. Future activities of TCRP and the Transportation Research Board (TRB) can explore topics in greater detail and more systematically. Furthermore, APTA's BRT standards development efforts can provide useful guidance for implementation of certain BRT elements and interfaces of elements.

This report ultimately relies on an openness to knowledge from all potential sources. This openness to knowledge from the broader transit community acknowledges the notion that BRT systems include elements that are not exclusive to BRT. The development of BRT systems involves conscious integration of several transit elements that can be implemented independently. Because the experience in these elements is broad, the body of research from which this report draws should be just as broad. The report can thus serve as a focal point for this dialogue between the transit research community and BRT system planners.

CLOSING REMARKS

This edition of "Characteristics of BRT" represents a snapshot of BRT experience as of Summer 2008. Even as it updates the wealth of data and information with four years of additional experience, there is much about BRT that can be explored further. This report will continue to be a dynamic document, one that evolves along with the experience of the global transit community with BRT. As the number and sophistication of BRT applications increases, "Characteristics of BRT" will reflect this experience in future editions. Data on system experience in future editions will allow for the analyses to be more robust and for lessons learned to be more definitive. The Federal Transit Administration encourages the use of this document as a tool to disseminate information on the evolution of BRT to the transit community.

REFERENCES

APTA (2007). "Contactless Fare Media System Standard, Part I (Introduction and Overview)."

Baltes, M., V. Perk, J. Perone, and C. Thole (2003). "South Miami-Dade Busway System Summary." National Bus Rapid Transit Institute, University of South Florida.

Ben-Akiva, M., and T. Morikawa (2002). "Comparing Ridership Attraction of Rail and Bus." *Transport Policy* 9: 107-116.

Booz Allen & Hamilton, Inc. (1995). "TCRP Report 2: Applicability of Low-Floor Light Rail Vehicles in North America." http://onlinepubs.trb.org/Onlinepubs/tcrp/tcrp_rpt_02.pdf

Brown, B., C. Werner, and N. Kim (2003). "Personal and Contextual Factors Supporting the Switch to Transit Use: Evaluating a Natural Transit Intervention." *Analyses of Social Issues and Public Policy* 3(1): 139-160.

Cain, A., and J. Sibley-Perone (2005). "Teenage Attitudes and Perceptions Regarding Transit Use." National Center for Transit Research, University of South Florida.

Callaghan, L., and W. Vincent (2007). "Bus Rapid Transit and Transit Oriented Development: Case Studies on Transit Oriented Development Around Bus Rapid Transit Systems in North America and Australia."

Cobb-Walgren, C., and L. Mohr (1998). "Symbols in Service Advertisements." *Journal of Services Marketing* 12(2): 129-151.

Crandall, W., B. L. Bentzen, L. Meyers, D. Steed, and Project ACTION (2003). "Talking Signs[R] Remote Infrared Signage: A Guide for Transit Managers." http://projectaction.easterseals.com/site/DocServer/95TSS.pdf?docID=18924

Currie, G. (2005). "The Demand Performance of Bus Rapid Transit." *Journal of Public Transportation* 8(1): 41-55.

Kantor, D., G. Moscoe, and C. Henke (2006). "Issues and Technologies in Level Boarding Strategies for BRT." *Journal of Public Transportation*, BRT Special Issue.

Forsyth, A., J. Jacobson, and K. Thering, in association with the American Institute of Architects (2007). *Moving Design: Spaces of Transportation*, Report #4 in the series: *Moving Communities Forward*. Center for Transportation Studies, University of Minnesota.

Heffner, R., T. Turrentine, and K. Kurani (2006). *A Primer on Automobile Semiotics*. Research Report UCD-ITS-RR-06-01, University of California, Institute of Transportation Studies.

Henke, C. (2007). "How Customer-Appealing Design and Branding Win New Riders: Data and Best Practices." Presented at the annual APTA Bus and Paratransit Conference, Nashville, May.

King, Rolland D. (1998). TCRP Report 41: "New Designs and Operating Experiences with Low-Floor Buses." http://onlinepubs.trb.org/Onlinepubs/tcrp/tcrp_rpt_41-a.pdf

Levinson, H., S. Zimmerman, J. Clinger, J. Gast, S. Rutherford, and E. Bruhn (2003). TCRP Report 90, Vol II: "Bus Rapid Transit - Implementation Guidelines." Transportation Research Board, Washington.

Meenaghan, T. (1995). "The Role of Advertising in Brand Image Development." *Journal of Product and Brand Management* 4(4): 23-34.

Milligan & Company (2003). "Bus Rapid Transit Evaluation of Port Authority of Allegheny County's West Busway Bus Rapid Transit Project." U.S. Department of Transportation, Washington, DC.

Neckar, L., in association with the American Institute of Architects (2007). "Synthesis, Report #7," *Moving Communities Forward*. Center for Transportation Studies, University of Minnesota: Minneapolis, MN.

Onkvisit, S., and J. Shaw (1989). "Service Marketing: Image, Branding, and Competition." *Business Horizons* 32(1): 13-19.

Peak, M., C. Henke, and L. Wnuk (2005). *Bus Rapid Transit Ridership Analysis.* FTA-CA-26-7068-2004.1, U.S. Federal Transit Administration.

Pultz, S. and D. Koffman (1987). "The Martin Luther King Jr. East Busway in Pittsburgh, PA," U.S. Department of Transportation, Washington, DC.

Rutenberg, U., and Hemily, B. (2003). TCRP Synthesis 50: "Use of Rear-Facing Position for Common Wheelchairs on Transit Buses." http://onlinepubs.trb.org/Onlinepubs/tcrp/tcrp_syn_50.pdf

Rutenberg, U., R. Baerg, M. MacNabb, A. K. Little, and B. Hemily (2007). "Assessment of Low-Floor Transit Bus G Forces on Rear-Facing Wheelchair Securement Systems." http://www.tc.gc.ca/tdc/publication/pdf/14400/14429e.pdf

Transit Cooperative Research Program (1997). TCRP Report 22: "The Role of Transit in Creating Livable Metropolitan Communities." Washington, D.C.: National Academy Press.

Transit Cooperative Research Program (2000). TCRP Report 63: "Enhancing the Visibility and Image of Transit in the United States and Canada." Washington, D.C.: National Academy Press.

Transportation Management & Design, Inc. (2002). "Final Report, Los Angeles Metro Rapid Demonstration Program." Los Angeles County Metropolitan Transportation Authority and Los Angeles Department of Transportation, Los Angeles.

Vincent, W., and L. Callaghan (2007). "A Preliminary Evaluation of the Metro Orange Line Bus Rapid Transit Project." Paper presented at the Annual Meeting of the Transportation Research Board, Washington, DC.

WestStart-CALSTART (2004). "BRT Vehicle Market Demand Study."

U.S. General Accounting Office (2001). *Mass Transit: Bus Rapid Transit Shows Promise*, GAO-01-984.

Zimmerman, S., and H. Levinson (2004). "Vehicle Selection for BRT: Issues and Options." *Journal of Public Transportation* 7(1): 83-103.

GLOSSARY OF BRT TERMS

TERM	DEFINITION
Alighting	When a passenger exits a vehicle.
Articulated Bus	A bus composed of two vehicle sections connected by an articulated joint. An articulated bus has a higher passenger capacity than a standard bus.
Automated Passenger Counter (APC)	Technology that counts passengers automatically when they board and alight vehicles. APC technologies include treadle mats (registers passengers when they step on a mat) and infrared beams (registers passengers when they pass through the beam). APC is used to reduce the costs of data collection and to improve data accuracy.
Automated Vehicle Location (AVL)	Technology used to monitor bus locations on the street network in real-time. AVL is used to improve bus dispatch and operation and allow for quicker response time to service disruptions and emergencies.
Barrier-Enforced Fare Payment System	A fare collection system (process) where passengers pay fares to pass through turnstiles or gates prior to boarding the vehicle. This is done to reduce vehicle dwell times.
Barrier-Free Proof-of-Payment (POP) System	A fare collection system (process) where passengers purchase fare media before boarding the vehicle and are required to carry proof of valid fare payment while on-board the vehicle. Roving vehicle inspectors verify that passengers have paid their fare. This is done to reduce vehicle dwell times.
Boarding	When a passenger enters a vehicle.
Branding	The use of strategies to differentiate a particular product from other products, in order to strengthen its identity. In the context of BRT systems, branding often involves the introduction of elements to improve performance and differentiate BRT systems, such as the use of vehicles with a different appearance from standard bus services, distinct station architecture, and the use of distinct visual markers such as color schemes and logos.
Brand Identity	Represents how a particular product is viewed among the set of other product options available. In the context of BRT systems, brand identity is necessary so that passengers distinguish BRT services from other transit services.
Bus Bulb	A section of sidewalk that extends from the curb of a parking lane to the edge of an intersection or offset through lane. This creates additional space for passenger amenities at stations, reduces street crossing distances for pedestrians, and eliminates lateral movements of buses to enter and leave stations. However, this may also produce traffic queues behind stopped buses.
Bus Rapid Transit (BRT)	A flexible, rubber-tired form of rapid transit that combines stations, vehicles, running way, and ITS elements into an integrated system with a strong identity. BRT applications are designed to be appropriate to the market they serve and to their physical surroundings. BRT can be implemented in a variety of environments, ranging from rights-of-way totally dedicated to transit (surface, elevated, or underground) to mixed traffic rights-of-way on streets and highways.
Bus Street	Street that is dedicated to bus use only.
Capacity	The maximum number of passengers that could be served by a BRT system.

TERM	DEFINITION
Capacity, Person	The maximum number of passengers that can be carried along the critical section of the BRT route during a given period of time, under specified operating conditions, without unreasonable delay, hazard, or restriction and with reasonable certainty.
Capacity, Facilities	The number of vehicles per period of time that use a specific facility (i.e., running way or station).
Capacity, Vehicle	The maximum number of seated and standing passengers that a vehicle can safely and comfortably accommodate. This is determined by the vehicle configuration.
Contextual Design	How well a BRT system demonstrates a premium, quality design and is integrated with the surrounding communities.
Demand	The actual number of passengers attracted to use a BRT system.
Designated Lane	A lane reserved for the exclusive use of BRT or transit vehicles. Dedicated lanes can be located in different positions relative to the arterial street and are classified accordingly: Concurrent Flow Curb – Next to the curb, used by buses to travel in the same direction as the adjacent lane. Concurrent Flow Interior – Between curb parking and the adjacent travel lane, used by transit vehicles to travel in the same direction as the adjacent travel lane. This is done in situations where curb parking is to be retained. Contraflow Curb – Located next to the curb, used by transit vehicles to travel in the opposite direction of the normal traffic flow. Could be used on one-way streets, or for a single block on two-way streets to enable buses to reverse direction. Median – Within the center of a two-way street.
Dual-Mode Propulsion	A propulsion systems that offers the capability to operate with two different modes, usually as a thermal (internal combustion) engine and in electric (e.g., trolley) mode.
Dwell Time	The time associated with a vehicle being stopped at a curb or station for the boarding and alighting of passengers. BRT systems often intend to reduce dwell times to the extent possible through such strategies as platform height, platform layout, vehicle configuration, passenger circulation enhancements, and the fare collection process.
Dwell Time Reliability	Ability to maintain consistent dwell times at stations. BRT systems often intend to improve dwell time reliabilities to the extent possible through such strategies as platform height, platform layout, vehicle configuration, passenger circulation enhancements, and the fare collection process.
Driver Assist and Automation Technology	A form of technology that provides automated controls for BRT vehicles. Examples include collision warning, precision docking, and vehicle guidance systems.
Fare Structure	Establishes the ways that fares are assessed and paid. The two basic types of fare structures are flat fares (same fare regardless of distance or quality of service) and differentiated fares (fare depends on length of trip, time of day, and/or type of service).

TERM	DEFINITION
Fare Transaction Media	Type of media used for fare payment. Examples include cash (coins and bills), tokens, paper media (tickets, transfers, flash passes), magnetic stripe media, and smart cards. Electronic fare transaction media (i.e., magnetic stripe media or smart cards) can reduce dwell times and fare collection costs, increase customer convenience, and improve data collection.
Global Positioning System (GPS)	The use of satellites and transponders to locate objects on the earth's surface. GPS is a widely used technology for AVL systems.
High Occupancy Vehicle (HOV) Lane	A street or highway lane designated for use only by vehicles with more than one passenger, including buses. HOV lanes are often used on freeways.
Hybrid-Electric Drive	A propulsion system using both an internal combustion engine and electric drives that incorporate an on-board energy storage device.
Intelligent Transportation Systems (ITS)	Advanced transportation technologies that are usually applied to improve transportation system capacity or to provide travelers with improved travel information. Examples of ITS applications with relevance to BRT systems include vehicle prioritization, driver assist and automation technology, operations management technology, passenger information, safety and security technology, and support technologies.
Internal Combustion Engine (ICE) (Thermal Engine)	An engine that operates by burning its fuel inside the engine. Combustion engines use the pressure created by the expansion of the gases to provide energy for the vehicle. ICEs typically use fuels such as diesel or natural gas (in either compressed gas or liquefied form).
Level Boarding	An interface between station platform and vehicle that minimizes the horizontal and vertical gap between the platform edge and the vehicle door area, which speeds up passenger boarding/alighting times and does not require the use of wheelchair lifts or ramps. Level boarding is often done through the use of station platforms and low-floor vehicles.
Low-Floor Vehicle	A vehicle designed with a lower floor (approximately 14 inches from pavement), without stairs or a wheelchair lift. Use of low-floor vehicles could be done in combination with station platforms to enable level boarding or could be done stand-alone such that passengers are required to take one step up or use a wheelchair ramp to board the vehicle.
Multiple-Door Boarding	Passengers are allowed to board the vehicle at more than one door, which speeds up boarding times. This typically requires off-board fare collection.
Operations Management Technology	Automation methods that enhance the management of BRT fleets to improve operating efficiencies, support service reliability, and/or reduce travel times. Examples include automated scheduling dispatch, vehicle mechanical monitoring and maintenance, and vehicle tracking systems.
Passing Capability	The ability for vehicles in service to pass one another. Bus pull-outs and passing lanes at stations are two primary ways to enhance passing capability for a BRT system.
Passenger Circulation Enhancement	Features that govern passenger accessibility to vehicles and circulation within vehicles. Examples include alternative seat layouts, additional door channels, and enhanced wheelchair securements.

TERM	DEFINITION
Passenger Information System	Technologies that provide information to travelers to improve customer satisfaction. The most common application relevant to BRT systems is the real-time provision of information pertaining to schedules, wait times, and delays to passengers at stations or on-board vehicles using variable message signs and an automated vehicle location technology.
Pay On-Board System	A fare collection system (process) in which passengers pay fares on-board the vehicle at the farebox or display valid fare media to the bus operator.
Platform	A station area used for passenger boarding and alighting. A side platform is adjacent to the curb or a running way. A center platform is located between the vehicle running way and the center of the running way, or median; this is less common because it requires non-standard vehicle door locations.
Platform Height	Height of the platform relative to the running way. The three basic options for platform height are standard curb, raised curb, and level platform.
Platform Layout	Design of the platform with respect to vehicle accommodation. The three basic options for platform layout are single vehicle length platform, extended (i.e., multiple vehicle) platform with unassigned berths, and extended platform with assigned berths.
Precision Docking System	A guidance system used to accurately steer vehicles into alignment with station platforms or curbs. These may be magnetic or optical-based and require the installation of markings on the pavement (paint or magnets), vehicle-based sensors to read the markings, and linkages with the vehicle steering system.
Propulsion System, Vehicle Propulsion System	The means of delivering power to enable vehicle movement. The most common propulsion systems for BRT vehicles include internal combustion engines fueled by diesel or compressed natural gas, electric drives powered by the use of an overhead catenary, and hybrid-electric drives with an on-board energy storage device. The choice of propulsion system affects vehicle capital costs, vehicle operating and maintenance costs, vehicle performance, ride quality, and environmental impacts.
Queue Jumper	A designated lane segment or traffic signal treatment at signalized or other locations where traffic backs up. Transit vehicles use this lane segment to bypass traffic queues (i.e., traffic backups). A queue jumper may or may not be shared with turning traffic.
Route Length	The length of the route affects what locations the route serves and the resources required to operate that route.
Route Structure	How stations and running ways are used to accommodate different vehicles that could potentially be serving different routes.
Running Time	Time that vehicles spend moving from station to station along the running way. BRT systems are designed to reduce running times to the extent possible through such strategies as running way segregation, passing capability, station spacing, ITS, and schedule control.
Running Time Reliability	Ability to maintain consistent running times along a route. BRT systems are designed to improve running time reliabilities to the extent possible through such strategies as running way segregation, passing capability, station spacing, ITS, and schedule control.

TERM	DEFINITION
Running Way	The space within which the vehicle operates. For BRT systems, the running way could be a fully grade-separated exclusive transitway, an at-grade transitway, a designated arterial lane, or a mixed-flow lane. BRT vehicles need not operate in a single type of running way for the entire route length.
Running Way Marking	The visible differentiation of the running ways used by BRT vehicles from other running ways. Signage and striping, raised lane delineators, and alternate pavement color/texture represent three major techniques.
Running Way Segregation	Level of segregation, or separation, of BRT vehicles from general traffic. A fully grade-separated exclusive transitway for BRT vehicles represents the highest level of segregation, followed by an at-grade transitway (second highest), a designated arterial lane (third highest), and a mixed flow lane (lowest).
Safety and Security Technology	Systems that enhance the safety and security of transit operations. Examples include silent alarms on the vehicle that can be activated by the driver and voice and/or video surveillance monitoring systems in stations or on-board vehicles.
Schedule Control	How vehicle on-time performance is monitored, either to meet specified schedules or to regulate headways. Headway-based control is more common for very high frequency routes.
Service Frequency	The interval of time between in-service vehicles on a particular route. Determines how long passengers must wait at stations and the number of vehicles required to serve a particular route. Service frequencies for BRT systems are typically high relative to standard bus services.
Service Reliability	Qualitative characteristics related to the ability of a transit operation to provide service that is consistent with its plans and policies and the expectations of its customers.
Service Span	The period of time that a service is available to passengers. Examples include all-day service and peak-hour-only service.
Signal Timing/Phasing	Involves changes to the normal traffic signal phasing and sequencing cycles in order to provide a clear path for oncoming buses.
Station	Location where passengers board and alight the vehicle. BRT stations can range from simple stops or enhanced stops to a designated station and an intermodal terminal or transit center. A station often has more passenger amenities than a stop (i.e., benches, shelters, landscaping, traveler information).
Station Access	Means of linking stations with adjacent communities in order to draw passengers from their market area. Examples include pedestrian linkages (i.e., sidewalks, overpasses, pedestrian paths) and park-and-ride facilities.
Station and Lane Access Control	Allows vehicle access to dedicated BRT running ways and stations with variable message signs and/or gate control systems.
Station Spacing	The spacing between stations impacts passenger travel times and the number of locations served along the route. Station spacings for BRT systems are typically farther apart relative to standard bus services.

TERM	DEFINITION
Support Technologies	Technologies used to support ITS applications. Examples include advanced communication systems, archived data, and automated passenger counters.
Ticket Vending Machine (TVM)	A fixed machine that accepts a combination of cash, stored-value media, and credit cards to dispense valid tickets and other fare media
Transfer Time	The time associated with a passenger waiting to transfer between particular transit vehicles. The network design determines where passengers need to make transfers. Service frequency and reliability are the primary determinants of transfer time.
Transit Signal Priority	Adjustments in signal timing to minimize delays to buses. Passive priority techniques involve changes to existing signal operations. Active priority techniques involve adjustments of signal timing after a bus is detected (i.e., changing a red light to a green light or extending the green time).
Transitway / Busway	Traffic lane dedicated to exclusive use of transit vehicles that is physically separated from other traffic lanes. May or may not be grade separated.
Validator	A device that reads a fare instrument (fare transaction medium) to verify if a fare paid is valid for the trip being taken by the passenger
Variable Message Sign (VMS)	A sign that provides flashing messages to its readers. The message posted on the sign is variable and can be changed in real-time.
Vehicle Configuration	The combination of length (standard, articulated, or specialized), body type (conventional, stylized, or specialized), and floor height (standard or low-floor) of the vehicle. In practice, BRT systems can use any combination of different vehicle configurations on a single running way.
Vehicle Guidance System	A guidance system used to steer vehicles on running ways while maintaining speed. These may be magnetic, optical, or GPS-based and require the installation of markings on the pavement (paint or magnets), vehicle-based sensors to read the markings, and linkages with the vehicle steering system. Guidance can be lateral (side-to-side to keep buses within a specified right-of-way) or longitudinal (to minimize the following distance between vehicles).
Vehicle Prioritization	Methods to provide travel preference or priority to BRT services. Examples include signal timing/phasing, station and lane access control, and transit signal priority.
Wait Time	The time associated with a passenger waiting at a station before boarding a particular transit service. Service frequency and reliability are the primary determinants of wait time.