TCRP
REPORT 90

TRANSIT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Transit Administration

Bus Rapid Transit

Volume 1: Case Studies in Bus Rapid Transit

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, The National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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FOREWORD

By Gwen Chisholm
Staff Officer
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TCRP Report 90: Bus Rapid Transit, which is published as a two-volume set, identifies the potential range of bus rapid transit (BRT) applications through 26 case studies and provides planning and implementation guidelines for BRT. This report will be useful to policy-makers, chief executive officers, and senior managers.

Increasing levels of urban congestion create the need for new transportation solutions. A creative, emerging public transit solution is BRT. While a precise definition of BRT is elusive, it is generally understood to include bus services that are, at a minimum, faster than traditional “local bus” service and that, at a maximum, include grade-separated bus operations. The essential features of BRT systems are some form of bus priority, faster passenger boarding, faster fare collection, and a system image that is uniquely identifiable. BRT represents a way to improve mobility at relatively low cost through incremental investment in a combination of bus infrastructure, equipment, operational improvements, and technology.

Despite the potential cost and mobility benefits, however, the transportation profession lacks a consolidated and generally accepted set of principles for planning, designing, and operating BRT vehicles and facilities. Transit agencies need guidance on how to successfully implement BRT in the political, institutional, and operational context of the United States. *Volume 1*: *Case Studies in Bus Rapid Transit* provides information on the potential range of BRT applications, planning and implementation background, and system description, including the operations and performance elements. *Volume 2: Implementation Guidelines* discusses the main components of BRT and describes BRT concepts, planning considerations, key issues, the system development process, desirable conditions for BRT, and general planning principles. It also provides an overview of system types.

This report was prepared by Herbert Levinson of New Haven, Connecticut, and DMJM+HARRIS of Fairfax, Virginia, in association with Scott Rutherford of Seattle, Washington; Rodney L. Smith of Carter & Burgess, Inc., Houston, Texas; John Cracknell of Maidenhead, United Kingdom; and Richard Soberman of Toronto, Canada. *Volume 1* examines BRT systems and services in 26 cities located in North America, Australia, Europe, and South America; the 26 case studies are on the accompanying CD-ROM (*CRP-CD-31)*. The report covers a geographically diverse group of communities and a broad range of applications. For each city’s BRT system, information is provided on design features, operating practices, institutional arrangements, costs, benefits, and relevance.

Both volumes issued under *TCRP Report 90* can be found on the TRB website at national-academies.org/trb.

CONTENTS

SUMMARY

Bus rapid transit (BRT) systems are found in cities throughout the world. Their operating flexibility and their ability to be built quickly, incrementally, and economically underlie their growing popularity. The systems vary in design, operations, usage, and effectiveness. Collectively, the case studies on BRT provided on the CD-ROM accompanying this volume give a wealth of information on BRT and how it should be planned and implemented.

This report draws on the experiences of 26 urban areas in North America, Australia, Europe, and South America. Most of the BRT systems reviewed are in revenue services, and a few are under construction or development. Information was assembled for each case study on institutional arrangements, system design, operating practices, usage, costs, and benefits.

S.1 WHAT IS BRT?

BRT can be defined for this study as a flexible, rubber-tired rapid-transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and they can be incrementally implemented in a variety of environments. In brief, BRT is an integrated system of facilities, services, and amenities that collectively improves the speed, reliability, and identity of bus transit.

BRT, in many respects, is rubber-tired light-rail transit (LRT), but with greater operating flexibility and potentially lower capital and operating costs. Often, a relatively small investment in dedicated guideways (or “running ways”) can provide regional rapid transit.

S.2 CASE STUDY LOCATIONS

The locations, urban populations, rail transit availability, and development status of the 26 case study cities are shown in Table 1. They include 12 urban areas in the United States (Boston, Charlotte, Cleveland, Eugene, Hartford, Honolulu, Houston, Los Angeles—

TABLE 1 Case study locations

CASE STUDY LOCATION	URBANIZED AREA POPULATION (MILLIONS)	RAIL TRANSIT IN METRO AREA?
NORTH AMERICA		
Boston, MA	3.0	√
Charlotte, NC	1.4	
Cleveland, OH	2.0	√
Eugene, OR (Lane Transit District)	0.2	
Hartford, CT	0.8	
Honolulu, HI	0.9	
Houston, TX	1.8	
Los Angeles County, CA	9.6[a]	√
Miami, FL	2.3	√
New York, NY	16.0	√
Ottawa, ON	0.7[b]	√
Pittsburgh, PA	1.7	√
Seattle, WA	1.8	
Vancouver, BC	2.1	√
AUSTRALIA		
Adelaide	1.1	√
Brisbane	1.5	√
Sydney	1.7	√
EUROPE		
Leeds, United Kingdom	0.7	
Rouen, France	0.4	√
Runcorn, United Kingdom	0.1	
SOUTH AMERICA		
Belo Horizonte, Brazil	2.2	√
Bogotá, Colombia	5.0	
Curitiba, Brazil	2.6	
Porto Alegre, Brazil	1.3	√
Quito, Ecuador	1.5	
Sao Paulo, Brazil	8.5	√

[a] Los Angeles County Only
[b] Excludes Hull, Quebec

three systems, Miami, New York—two systems, Pittsburgh, and Seattle); 2 cities in Canada (Ottawa and Vancouver); 3 cities in Australia (Adelaide, Brisbane, and Sydney); 3 in Europe (Leeds, Runcorn, and Rouen); and 6 in South America (Belo Horizonte, Bogotá, Porto Alegre, Curitiba, Quito, and Sao Paulo).

Most of these BRT systems are found in urban areas with over 700,000 in population. Many of these urban areas also have rail rapid transit. Twenty-one systems are in revenue service, and five are under construction, in development, or planned.

S.3 REASONS FOR IMPLEMENTING BRT

Transportation and community-planning officials all over the world are examining improved public transportation solutions to mobility issues. This renewed interest in transit reflects concerns ranging from environmental consciousness to the desire for alternatives to clogged highways and urban sprawl. These concerns have led to a re-examination of existing transit technologies and the embrace of new, creative ways of providing transit service and performance. BRT can be an extremely cost-effective way of providing high-quality, high-performance transit.

The case studies report that the main reasons for implementing BRT systems were lower development costs and greater operating flexibility as compared with rail transit.

Other reasons are that BRT is a practical alternative to major highway reconstruction, an integral part of the city's structure, and a catalyst for redevelopment. A 1976 study in Ottawa, for example, found that a bus-based system could be built for half of the capital costs of rail transit, and it would cost 20% less to operate (for study details, see Ottawa case study). In Boston, BRT was selected because of its operational and service benefits, rather than its cost advantages.

S.4 FEATURES OF BRT

The main features of BRT include dedicated running ways, attractive stations and bus stops, distinctive easy-to-board vehicles, off-vehicle fare collection, use of ITS technologies, and frequent all-day service (service should operate at least 16 hours each day, with midday headways of 15 minutes or less and peak headways of 10 minutes or less). Table 2 summarizes these BRT features by continent for the 29 systems analyzed.

Over 80% of the systems in the case studies have some type of exclusive running way—either a bus-only road or bus lane. More than 75% provide frequent all-day services, and about 66% have "stations" in addition to the usual bus stops. In contrast, only about 40% of the systems have distinctive vehicles or ITS applications, and only 17% (five systems) have or will have off-vehicle fare collection. Three existing systems have all six basic features, including Bogotá's TransMilenio, Curitiba's median busways, and Quito's Trolebus. Several systems under development (e.g., Boston, Cleveland, and Eugene) will have most BRT elements.

S.4.A Running Ways

Running ways for BRT include mixed traffic lanes, curb bus lanes, and median busways on city streets; reserved lanes on freeways; and bus-only roads, tunnels, and bridges. Table 3 summarizes the various running ways found in the BRT case studies.

Examination of the case study data shows that busways dominate North American practice, whereas median arterial busways are widely used in South America. Reversible high occupancy vehicle (HOV) lanes in freeway medians are found only in the United States. Bus tunnels, such as the one under construction in downtown Boston and those that exist in Brisbane and Seattle, bring a major feature of rail transit to BRT. In most of the case studies, the running ways are radial, extending to or through the city center.

TABLE 2 Number of facilities with specific features

Feature	US / Canada	Australia & Europe	South America	**Total Systems**	**Percent of Total**
Running Way	13	5	6	**24**	**83**
Stations	12	4	3	**19**	**66**
Distinctive Vehicles	7	1	3	**11**	**38**
Off-Vehicle Fare Collection	2	0	3	**5**	**17**
ITS	7	1	3	**11**	**38**
Frequent All-Day Service	11	5	6	**22**	**76**
Total Systems	17	6	6	**29**	**100**

Note: Refer to Appendix A to see details on each individual case study.

TABLE 3 Running way characteristics

LOCATION	BUS TUNNEL	BUSWAY (SEPARATE RIGHT-OF-WAY)	FREEWAY BUS LANES	ARTERIAL MEDIAN BUSWAYS	BUS LANES	MIXED TRAFFIC
North America	Boston Seattle	Charlotte New Britain – Hartford Miami Ottawa Pittsburgh	Houston Los Angeles New York	Cleveland Eugene	Ottawa Pittsburgh Vancouver	Honolulu Los Angeles Vancouver
Australia	Brisbane	Adelaide[a] Brisbane Sydney				
Europe		Runcorn			Rouen [c]	Leeds [b]
South America				Belo Horizonte Bogotá [d] Curitiba[d] Porto Alegre[d] Quito [d] Sao Paulo		

[a] O-Bahn technology
[b] Guided bus with queue bypass
[c] Optically guided bus
[d] High-platform stations

S.4.B Stations

The spacing of stations along freeways and busways ranges from 2,000 to almost 7,000 feet, enabling buses to operate at high speeds. Spacing along arterial streets ranges upward from about 1,000 feet (e.g., Cleveland and Porto Alegre) to over 4,000 feet (e.g., Vancouver and Los Angeles).

Most stations are located curbside or on the outside of bus-only roads and arterial median busways. However, the Bogotá system, a section of Quito's Trolebus, and Curitiba's "direct" service have center island platforms and vehicles with left-side doors.

Busways widen to three or four lanes at stations to enable express buses to pass stopped buses. South America's arterial median busways also provide passing lanes. Stations and passing lanes can be offset to minimize the busway envelope.

Most BRT stations have low platforms because many are or will be served by low-floor buses. However, Bogotá's TransMilenio, Quito's Trolebus, and Curitiba's all-stop and direct services provide high platforms and buses that are specially equipped with a large ramp that deploys at stations to allow level passenger boarding and alighting. Each of these systems also has off-vehicle fare collection. Rouen features optically guided Irisbus Civis vehicles that provide the minimum gap for level boarding and alighting.

Stations in the case study cities provide a wide range of features and amenities depending upon locations, climate, type of running way, patronage, and available space. Overhead walks with fences between opposite directions of travel are provided along busways in Brisbane, Ottawa, and Pittsburgh.

S.4.C Vehicles

Conventional standard and articulated diesel buses are widely used for BRT operations. There is, however, a trend toward innovations in vehicle design. These innovations include (1) "clean" vehicles (e.g., low-sulfur diesel fuel, diesel-electric hybrids, compressed natural gas [CNG], and possibly fuel cells in the future); (2) dual-mode (diesel-electric) operations through tunnels; (3) low-floor buses; (4) more doors and wider doors; and (5) use of distinctive, dedicated BRT vehicles.

Examples of innovative vehicle designs include the following:

- Los Angeles's low-floor red-and-white CNG vehicles;
- Boston's planned multidoor, dual-mode, diesel-electric and CNG buses;
- Curitiba's double articulated buses with five sets of doors and high-platform loading; and
- Rouen's Irisbus Civis bus—a "new design" hybrid diesel-electric articulated vehicle with train-line features, four doors, the ability to be optically guided, and a minimum 34-inch-wide aisle end to end.

S.4.D ITS

Applications of ITS technologies include automatic vehicle location systems; passenger information systems; and transit preferential treatment systems at signalized intersections, controlled tunnel or bridge approaches, toll plazas, and freeway ramps. The Metro Rapid routes in Los Angeles can get up to 10 seconds additional green time when buses arrive at signalized intersections. ITS can also help provide priorities for buses at freeway ramps, toll plazas, and bridge or tunnel approaches.

S.4.E Service Patterns

Service patterns reflect the types of running way and vehicles utilized. Many systems provide an "overlay" of express (or limited-stop) service on top of all-stop (or local) service and "feeder" bus line services at selected stations. Service in most systems extends beyond the limits of busways or bus lanes—an important advantage of BRT. However, the Bogotá, Curitiba, and Quito systems—because of door arrangements, platform heights, and/or propulsion systems—operate only within the limits of the special running ways.

S.5 PERFORMANCE

The performance of the BRT systems evaluated in the case studies ranges widely because of the configuration of each system. For the purposes of this report, performance is measured in terms of passengers carried, travel speeds, and land development changes.

S.5.A Ridership

The number of weekday bus riders reported for systems in North America and Australia ranges upward from 1,000 in Charlotte to 40,000 or more in Los Angeles, Seattle, Adelaide, and Brisbane. Daily ridership in Ottawa and the South American cities is substantially higher and usually exceeds 150,000 per day.

Examples of the heavier peak-hour, peak-direction passenger flows at the maximum load points are shown in Table 4. These flows equal or exceed the number of LRT transit passengers carried per hour in most U.S. and Canadian cities and approach metro (rail rapid transit) volumes.

Reported increases in bus riders because of BRT investments reflect expanded service, reduced travel times, improved facility identity, and population growth. Examples of ridership gains reported in the case studies include the following:

- 18% to 30% of riders were new riders in Houston;
- Los Angeles had a 26% to 33% gain in riders, one-third of which was new riders;

TABLE 4 Peak-hour, peak-direction passenger flows

Over 20,000 per hour	New York: approach to Lincoln Tunnel Bogotá's TransMilenio Porto Alegre Sao Paulo
8,000–20,000 per hour	Belo Horizonte Ottawa Quito Curitiba Brisbane

- Vancouver had 8,000 new riders, 20% of whom previously used automobiles and 5% of whom were taking new trips;
- Adelaide had a 76% gain in ridership;
- Brisbane had a 42% gain in ridership;
- Leeds had a 50% gain in ridership; and
- Pittsburgh had a 38% gain in ridership.

S.5.B Speeds

Operating speeds reflect the type of running way, station spacing, and service pattern. Typical speeds are shown in Table 5.

S.5.C Travel Time Savings

Reported travel time savings over pre-BRT conditions are illustrated in Table 6. Busways on dedicated rights-of-way generally save 2 to 3 minutes per mile compared with pre-BRT conditions, including time for stops. Bus lanes on arterial streets typically save 1 to 2 minutes per mile. The time savings are greatest where the bus routes previously experienced major congestion. Pittsburgh, for example, has reported travel time savings up to 5 minutes per mile during peak hours.

S.5.D Land Development Benefits

Reported land development benefits with full-featured BRT are similar to those experienced along rail transit lines. Studies have indicated that construction of the Ottawa Transitway has led to up to $675 million (U.S. dollars) in new construction around transit stations; a study completed by the Port Authority of Allegheny County reported $302 million in new and improved development along the East Busway, 80% of which was clustered at stations. Property values near Brisbane's South East Busway grew 20%, which is largely attributed to the busway construction.

TABLE 5 Typical operating speeds

Freeway-Busway	
• Nonstop	40–50 mph
• All-Stop	25–35 mph
Arterial Streets	
• Express, Bogotá, Curitiba	19 mph
• Metro Rapid bus, Ventura Blvd., Los Angeles	19 mph
• Metro Rapid bus, Wilshire Blvd., Los Angeles	14 mph
• All-stop–Median Busways, South America	11–14 mph
• Limited-Stop–New York City	8–14 mph

TABLE 6 Examples of travel time savings

Busways, Freeway Lanes	32%–47%
Bus Tunnel–Seattle	33%
Bogotá	32%
Porto Alegre	29%
Los Angeles Metro Rapid Bus	23%–28%

S.6 COSTS

Facility development costs reflect the location, type, and complexity of construction. Reported median costs were $272 million per mile for bus tunnels (2 systems), $7.5 million per mile for busways (12 systems), $6.6 million per mile for arterial median busways (5 systems), $4.7 million per mile for guided bus operations (2 systems), and $1 million per mile for mixed traffic or curb bus lanes (3 systems). Operating costs reflect the ridership, type of running way, and operating environment. Comparisons of BRT and light-rail operating costs suggest that BRT can cost the same or less to operate per passenger trip than LRT.

S.7 IMPLICATIONS AND DIRECTIONS

Each urban area has unique circumstances that influence BRT markets, service patterns, viability, design, and operations. Within this context, several key lessons, implications, and directions have emerged from the case studies. Many of these lessons can also apply to rapid-transit planning and development in general.

BRT system development should be an outgrowth of a planning and project development process that addresses demonstrated needs and problems. An open and objective process should be considered through all phases of BRT development.

Early and continuous community support from elected leaders and citizens is essential. Public decision makers and the general community must understand the nature of BRT and its potential benefits. BRT's customer attractiveness, operating flexibility, capacities, and costs should be clearly and objectively identified in alternatives analyses that consider other mobility options as well.

State, regional, and local agencies should work together in planning, designing, and implementing BRT. This requires close cooperation of transit service planners, city traffic engineers, state department of transportation (DOT) highway planners, and urban land planners. Metropolitan planning agencies and state DOTs should be major participants.

Incremental development of BRT will often be desirable. Incremental development may provide an early opportunity to demonstrate BRT's potential benefits to riders, decision makers, and the general public while still enabling system expansion and possible upgrading. Examples of staging flexibility are as follows:

- BRT may be initially developed as a basic low-cost project, such as with curbside bus lanes. The running way could be upgraded to busways in the future.
- BRT may serve as a means of establishing the transit market for a possible future rail line.

BRT systems should be beneficial in terms of usage, travel time savings, costs, development effects, and traffic impacts. These benefits are greater when the system contains more BRT elements. Therefore, corners should not be cut in the development of BRT systems.

Parking facilities should complement, not undercut, BRT. Adequate parking is essential at stations along high-speed transitways in outlying areas. It may be desirable to manage downtown parking space for employees, especially where major BRT investments are planned.

BRT and land use planning in station areas should be integrated as early as possible. Adelaide, Brisbane, Ottawa, Pittsburgh, and Curitiba have demonstrated that BRT can have land use benefits similar to those resulting from rail transit. Close working relationships with major developers may be necessary in addressing issues of building orientation, building setbacks, and connections to stations.

BRT should serve demonstrated transit markets. Urban areas with more than a million residents and a central area of employment of at least 75,000 are good candidates for BRT. These areas generally have sufficient corridor ridership demands to allow frequent all-day service. BRT works well in physically constrained environments where hills, tunnels, and water crossings result in frequent traffic congestion.

It is essential to match markets with rights-of-way. The presence of an exclusive right-of-way, such as along a freeway or railroad corridor, is not always sufficient to ensure effective BRT service. This is especially true where the rights-of-way are removed from major markets and where the stations are inaccessible. Ideally, BRT systems should be designed to penetrate major transit markets. In addition, stations should be designed to be easily accessible by several modes such as bicycles, walking, transit, and individual automobiles.

The key attributes of rail transit should be transferred to BRT, whenever possible. These attributes include segregated or priority rights-of-way; attractive stations; off-vehicle fare collection; quiet, easily accessible multidoor vehicles; and clear, frequent, all-day service. A successful BRT project requires more than merely providing a queue bypass, bus lane, or dedicated busway. It requires the entire range of rapid-transit elements and the development of a unique system image and identity. Speed, service reliability, and an all-day span of service are extremely important. It is important to provide easy access to stations for pedestrians, bus passengers, automobile drivers and passengers, and cyclists.

BRT should be rapid. This is best achieved by operating on exclusive rights-of-way wherever possible and maintaining wide spacing between stations.

Separate rights-of-way can enhance speed, reliability, safety, and identity. These running ways can be provided as integral parts of new town development or as an access framework for areas that are under development. They may also be provided in denser, established urban areas where right-of-way is available. Bus tunnels may be justifiable where congestion is frequent, bus and passenger volumes are high, and street space is limited.

The placement, design, and operation of bus lanes and median busways on streets and roads must balance the diverse needs of buses, delivery vehicles, pedestrians, and general traffic flows. For example, curb lanes allow curbside boarding and alighting, but the lanes are often difficult to enforce. Median busways provide greater identity and avoid curbside interferences, but they may pose problems with left turns and pedestrian access. Moreover, they generally require streets that are at least 75 feet in width from curb to curb.

Vehicle design, station design, and fare collection procedures should be well coordinated. Adequate berthing capacity should be provided as well as passing lanes for express buses (on busways) and amenities for passengers. Buses should be distinctively designed and delineated and provide sufficient passenger capacity, multiple doors, and low-floors for easy passenger access. There should also be ample interior circulation space. Off-vehicle fare collection is desirable, at least at major boarding points. Achieving these features calls for changes in operating philosophies and practices. ITS and smart card technology applied at multiple bus doors may facilitate rapid on-board payment without losing revenues.

Coordinated traffic engineering and transit service planning is essential for BRT system design. This coordination is especially critical in designing running ways, locating bus stops and turn lanes, applying traffic controls, and establishing traffic signal priorities for BRT.

BRT service can extend beyond the limits of dedicated running ways, where a reliable, relatively high-speed operation can be sustained. Outlying sections of BRT lines can use HOV or bus lanes or even operate in the general traffic flow.

BRT services should be keyed to markets. The maximum number of buses during peak hour should meet ridership demands and simultaneously minimize bus-bus congestion. Generally, frequent, all-stop, trunk-line service throughout the day should be complemented by an "overlay" of peak-period express services serving specific markets. During off-peak periods, overlay services could operate as feeders (or shuttles) that are turned back at BRT stations.

S.8 PROSPECTS FOR BRT

The case studies summarized here demonstrate that BRT does work. It can attract new riders and induce transit-oriented development. It can be more cost-effective and provide greater operating flexibility than rail transit. BRT also can be a cost-effective extension of rail transit lines. Generally, BRT systems can provide sufficient capacity to meet peak-hour travel demands in most U.S. corridors.

One of the key lessons learned from the case studies is that BRT should be rapid. Reliably high speeds can be best achieved when a large portion of the service operates on separate rights-of-way. In addition, any major BRT investment should be reinforced by transit-supportive land development and parking policies.

It is expected that more cities will examine and implement BRT systems. There will be a growing number of fully integrated systems and even more examples of selected BRT elements being implemented. These efforts will lead to substantial improvements in urban transit access, mobility, and quality of life.

CHAPTER **1**

INTRODUCTION

BRT has become increasingly popular in cities throughout the world. Reasons for this popularity include BRT's flexibility and ability to be built quickly, incrementally, and economically. In the United States, its development has been spurred by the FTA's BRT initiative.

From Belo Horizonte to Brisbane, Bogotá to Boston, Cleveland to Curitiba, Hartford to Honolulu, and Pittsburgh to Porto Alegre, cities have implemented or are developing BRT systems. The systems are varied, and the reasons for their development are diverse. Collectively, they provide a wealth of information on BRT planning/implementation, design, and operations.

1.A PURPOSE AND SCOPE

This volume of *TCRP Report 90: Bus Rapid Transit* draws on the broad range of experience that has become available and that may help communities in planning new BRT systems or in upgrading existing systems. It is the first of two volumes published as *TCRP Report 90: Bus Rapid Transit* and one of three documents covering TCRP Project A-23, "Implementation Guidelines for Bus Rapid Transit Systems."

The first document, "BRT—Why More Communities Are Choosing Bus Rapid Transit," is an informational brochure that was published in 2001. The third document is the second volume of *TCRP Report 90: Bus Rapid Transit*, which covers implementation guidelines for BRT.

In addition, the project team compiled a video library, which is accessible on-line at http:\\brt.ce.Washington.edu\Filehouse\GetUser.asp. (The access code is ID = TCRP with Password = A-23.) It contains numerous videos, video clips, and still photos of BRT systems and features. These materials illustrate BRT systems; how BRT can be planned and implemented; and how well BRT works in terms of usage, speed, benefits, and costs. These materials, which are being continually updated, provide important resource information on BRT.

The overall research objectives of TCRP Project A-23 were (1) to identify the potential range of BRT applications and (2) to develop descriptive information and technical guidance tailored to meet the needs of various stakeholders interested in BRT as a means of improving mobility.

1.B CASE STUDY CITIES

The case studies analyze BRT systems and services in 26 cities located in North America, Australia, Europe, and South America. They cover a geographically diverse group of communities and a broad range of applications. They provide important information and insights that may be applicable elsewhere.

The case study cities are shown in the list below. These cities were selected in terms of the services provided, information available, geographic diversity, lessons learned, and relevance for North American cities. They include 14 cities in the United States and Canada, 3 in Australia, 3 in Europe, and 6 in South America. Most systems are generally in revenue service, although a few are under construction or in advanced planning. Comprehensive case studies were done for 12 cities, and shorter briefs were prepared for the remainder of the cities.

List of Case Studies

North America
- Boston, MA
- Charlotte, NC*
- Cleveland, OH
- Eugene, OR (Lane Transit District)*
- Hartford, CT
- Honolulu, HI*
- Houston, TX*
- Los Angeles, CA
- Miami, FL
- New York, NY
- Ottawa, ON
- Pittsburgh, PA
- Seattle, WA*
- Vancouver, BC

Australia
- Adelaide
- Brisbane*
- Sydney*

Europe
- Leeds, United Kingdom*
- Rouen, France*
- Runcorn, United Kingdom*

South America
- Belo Horizonte, Brazil*
- Bogotá, Colombia*
- Curitiba, Brazil
- Porto Alegre, Brazil*
- Quito, Ecuador
- Sao Paulo, Brazil*

**denotes brief*

For each city, information was assembled and analyzed on design features, operating practices, institutional arrangements, costs, benefits, and relevance. Twelve case studies were developed in depth, whereas another 14 were developed as shorter "briefs" that reported salient findings. Information was assembled on the following topics:

- **Context**—population, area, central business district (CBD) employment, physical features, and transit use;

- **Planning and implementation background**—how and why the system was implemented, including reasons for implementation (or nonimplementation), and community attitudes;
- **System description**—physical elements (turning way, stations, vehicles, and ITS), operations (service patterns, fare collection practices), and performance (speeds, ridership, benefits, and costs); and
- **General assessment**—the system's strengths and weaknesses, factors contributing to its success, lessons learned, and applications elsewhere.

Each case study is generally organized into these four major categories.

1.C ORGANIZATION OF THE CASE STUDY REPORT

The case study report was organized to present a general synthesis of the case studies, as well as more detailed information on each individual BRT system. The chapters of the report are organized as follows:

- Chapter 1 provides a general introduction to TCRP Project A-23 and to the case study report.
- Chapter 2 provides a synthesis of findings including a basic definition of BRT and the concepts behind it and a comparison of the systems in terms of features, performance, costs, and benefits.
- Chapter 3 sets forth the various lessons learned and their implications.
- Appendix A includes summary tables that compare all the BRT systems examined in the case studies.
- Appendix B (available on *CRP-CD-31*, which accompanies this volume) includes the individual case studies. The systems are grouped by continent (North America, Europe, South America, and Australia) and are then arranged alphabetically within each group.

These case study materials will be useful to communities that are considering BRT as a potential solution to mobility issues, communities that are planning to develop BRT systems, and communities that are examining strategies for upgrading their existing bus services.

CHAPTER **2**

SYNTHESIS OF FINDINGS

This chapter synthesizes the experience of 26 case studies of BRT located in the United States, Canada, Australia, Europe, and South America. It starts by defining the concepts and attributes of BRT and traces BRT's evolution over the years. It then identifies where BRT systems operate and how they were successfully implemented. The case studies are then compared in terms of physical features (running ways, stations, vehicles, and ITSs); performance (ridership and speeds); and benefits achieved.

2.A BRT—CONCEPTS AND EVOLUTION

There is a broad range of perspectives as to what constitutes BRT. At one end of the spectrum, BRT has been defined as a corridor in which buses operate on a dedicated right-of-way such as a busway or a bus lane reserved for buses on a major arterial road or freeway. Although this definition describes many existing BRT systems, it does not capture the other features that have made rail rapid-transit modes so attractive around the world.

BRT has also been defined as a bus-based, rapid-transit service with a completely dedicated right-of-way and on-line stops or stations, much like LRT. This is consistent with the FTA definition of BRT as "a rapid mode of transportation that can combine the quality of rail transit and the flexibility of buses" (*1*).

For the purpose of this project, BRT has been defined more comprehensively as a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways, and ITS elements into a fully integrated system with a strong image and identity. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and they can be incrementally implemented in a variety of environments (from rights-of-way totally dedicated to transit to streets and highways where transit is mixed with traffic).

In brief, BRT is a fully integrated system of facilities, services, and amenities that are designed to improve the speed, reliability, and identity of bus transit. In many respects, it is rubber-tired LRT, but with greater operating flexibility and potentially lower capital and operating costs. Often, a relatively small investment in dedicated guideways can provide regional rapid transit. This definition has the following implications:

- Where BRT vehicles (buses) operate totally on exclusive or protected rights-of-way (surface, elevated, and/or tunnel) with on-line stops, the level of service provided is similar to that of heavy rail rapid transit (metros).
- Where buses operate in combinations of exclusive rights-of-way, median reservations, bus lanes, and street running with on-line stops, the level of service provided is similar to that of LRT.
- Where BRT operates almost entirely on exclusive bus or HOV lanes on highways (freeways and expressways) to and from transit centers with significant parking and where it offers frequent peak service focused on a traditional CBD, it provides a level of service very similar to that of commuter rail.
- Where buses operate mainly on city streets with little or no special signal priority or dedicated lanes, the level of service provided is similar to that of an upgraded limited-stop bus or tram system.

Figure 1 describes the seven major components of BRT—running ways, stations, vehicles, service, route structure, fare collection, and ITS. Collectively, these components form a complete rapid-transit system that can improve customer convenience and system performance (*2*).

2.A.1 Why BRT?

Transportation and community-planning officials all over the world are examining improved public transportation solutions to mobility issues. This renewed interest in transit reflects concerns ranging from environmental consciousness to the desire for alternatives to clogged highways and urban sprawl. These concerns have led to a re-examination of existing transit technologies and the embrace of new, creative ways of providing transit service and performance. BRT can be an extremely cost-effective way of providing high-quality, high-performance transit.

Advancements in technology such as clean air vehicles, low-floor vehicles, and electronic and mechanical guidance

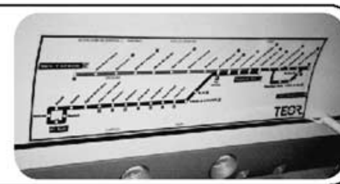
Running Ways	BRT vehicles operate primarily in fast and easily identifiable exclusive transitways or dedicated bus lanes. Vehicles may also operate in general traffic.	
Stations	BRT stations, ranging from enhanced shelters to large transit centers, are attractive and easily accessible. They are also conveniently located and integrated into the community they serve.	
Vehicles	BRT uses rubber-tired vehicles that are easy to board and comfortable to ride. Quiet, high-capacity vehicles carry many people and use clean fuels to protect the environment.	
Services	BRT's high-frequency, all-day service means less waiting and no need to consult schedules. The integration of local and express service can reduce long-distance travel times.	
Route Structure	BRT uses simple, often color-coded routes. They can be laid out to provide direct, no-transfer rides to multiple destinations.	
Fare Collection	Simple BRT fare collection systems make it fast and easy to pay, often before you even get on the bus. They allow multiple door boarding, reducing time in stations.	
Intelligent Transportation Systems	BRT uses advanced digital technologies that improve customer convenience, speed, reliability, and operations safety.	

Figure 1. Components of bus rapid transit.

systems have made BRT a more attractive transit alternative to both transit users and transportation-planning officials. Several reasons were cited repeatedly in the case studies for considering BRT as a potential high-performance transit investment. These reasons are the following:

- Continued growth of urban areas, including many CBDs and suburban activity centers, has created a need for improved transport capacity and access. Given the costs and community impacts associated with major road construction, improved and expanded public transit emerges as an important way to provide the needed transportation capacity. However, existing conventional bus systems are often unattractive, difficult to use, slow, unreliable, and infrequent in service. In addition, their vehicles are often not well matched to their markets, and they have little if any passenger information and amenities at stops. Rail transit can be difficult, time-consuming, and expensive to implement; costly to operate; and poorly suited to many suburban travel markets.
- BRT can often be implemented quickly and incrementally without precluding future rail investment if and when it is warranted.
- For a given distance of dedicated running way, BRT is generally less costly to build and equip than rail transit. Moreover, there are relatively low facility costs where BRT vehicles operate on existing bus-only or HOV lanes or in mixed traffic.
- BRT can be cost-effective in serving a broad variety of urban and suburban environments. BRT vehicles, whether driver-steered or guided mechanically or electronically, can operate on streets, freeway medians, railroad rights-of-way, arterial structures, and underground. BRT can easily and inexpensively provide a broad array of express, limited-stop, and local all-stop services on a single facility, unlike most rail systems.
- BRT can provide quality performance with sufficient transport capacity for corridor applications in most U.S. and Canadian cities. The Ottawa Transitway system's CBD link, for example, carries more people in the peak-hour peak direction than most LRT segments in North America. Many BRT lines in South American cities carry peak-hour passenger flows that equal or exceed those on many U.S. and Canadian fully grade-separated rail rapid-transit lines.
- At the ridership levels typically found in most urban corridors, BRT can have relatively low operations and maintenance costs. This is primarily because the relatively low fixed maintenance costs can offset variable driver costs.
- BRT is well suited to cost-effectively extend the reach of existing rail transit lines by providing feeder services to areas where densities are currently too low to support rail transit. It can also serve as the first stage for an eventual rail transit line.
- Like other forms of rapid transit, BRT can be integrated into urban and suburban environments in ways that foster economic development and transit- and pedestrian-friendly design. Examples of regions that have integrated BRT successfully include Adelaide, Boston, Ottawa, and Brisbane.
- Advancements in the practical application of several technologies also make BRT feasible. These include
  - "Clean" vehicles (CNG, diesel-electric hybrid, and dual power buses);
  - Low-floor vehicles that allow quick, level boarding; and
  - Mechanical, optical, and electronic guidance systems.

2.A.2 Evolution of BRT

The idea of using rubber-tired vehicles (buses) to provide rapid transit is not new. Plans and studies have been prepared since the 1930s, with a growing emphasis on rubber-tired vehicles in the last few years.

Major Proposals

BRT proposals were developed for Chicago in 1937, Washington D.C. in 1956–1959, St. Louis in 1959, and Milwaukee in 1970. These plans are discussed briefly below.

1937 Chicago Plan. BRT was first suggested in Chicago (*3*). A 1937 plan called for converting three westside rail rapid-transit lines to express bus operation on super highways with on-street distribution in central areas and downtown.

1956–1959 Washington D.C. Plan. Design studies for BRT within freeway medians were developed as part of the 1956–1959 "Mass Transportation Survey for the National Capital Region" (*4*). It was recommended that "in planning of future radial freeways a cross section . . . be provided to afford maximum flexibility and reserve capacity for vehicles as well as for the mass movement of people." This plan called for a three- or four-lane roadway for traffic in each direction. These roadways would be separated by a 64-foot mall with 51 feet from center to center of the columns supporting cross-street bridges. In the first stage, this wide mall would be landscaped and held available for future developments; public transportation would consist of express buses operating in the general traffic lanes.

Buses would make stops at appropriate intervals on the parallel service roads without special station facilities or at simple stations within the end span of the cross-street bridges. Express bus service eventually would be converted to BRT and rail within the median.

1959 St. Louis Plan. The 1959 transportation plan included an 86-mile BRT system, of which 42 miles were to be special grade-separated bus roadways (*5*). The focus of this proposal was an elevated loop road circling downtown St. Louis, measuring six blocks north and south and five blocks east and west. The loop contained a 60-foot-wide operating deck that included a sidewalk or passenger-loading platform located on the inner side of the deck to mesh with one-way clockwise operation of buses. It provided a three-lane bus roadway approximately 37 feet wide. The BRT system cost totaled $175 million (exclusive of freeways).

1970 Milwaukee Plan. Milwaukee's proposed 1970 transitway plan included 107 miles of express bus routes over the freeway system and an 8-mile, east-west transitway (*6*). The plan called for 39 stations (excluding downtown) and 33,000 parking spaces.

In 1990, during the p.m. peak hour, 600 buses would enter the Milwaukee CBD as compared with 135 in 1973. Costs for the BRT system were estimated at $151 million (1970), $40 million of which was for the transitway. The plan was integrated with existing and proposed freeways.

Research and Planning Studies

Several research studies described where BRT would work and how it might be configured. A 1966 study done for the American Automobile Manufacturers Association, *Transportation and Parking for Tomorrow's Cities* (*7*), set forth broad transportation-planning guidelines. It indicated that "bus rapid transit is especially suitable in cities where downtown must attract its visitors from a wide, diffused area." It stated that

> BRT could involve lower capital costs, provide greater coverage, better serve low and medium-density areas, and more readily adapt to changing land-use and population patterns than rail-based systems.
>
> BRT also has applicability in larger cities of much higher density because of its operational flexibility, and with proper downtown terminal design, bus rapid transit systems could provide adequate capacities to meet corridor demands in nearly all of the Nation's cities which do not have rail systems.

To achieve high average speeds on downtown approaches, buses could operate within reserved lanes or exclusive freeway rights-of-way on key radial routes and could travel outward to the intermediate freeway loop, with provision for subsequent expansion.

Downtown, buses would operate preferably on private rights-of-way and penetrate the heart of the core area (either above or below ground) or, alternatively, they could enter terminals. Successful BRT, however, would require

> careful coordination between highway and transit officials in all stages of major facility planning. In this regard, resolution of several major policy questions will go far toward early implementation of bus rapid transit systems. These are: (1) the extent to which exclusive bus facilities will qualify for federal aid under existing programs; (2) the need for separate designs on approaches to the inner freeway loops and downtown; (3) the minimization or elimination of costly ventilation systems to facilitate underground operation; (4) the development of financing policies for downtown bus tunnels; and (5) the development of bus trains or special bus designs to minimize downtown station requirements and expedite downtown loading. (*7*)

The 1996 study indicated that a small amount of special right-of-way in conjunction with the urban freeway system (where necessary to ensure good peak-hour speeds) could generally provide effective regional rapid transit. It was conservatively estimated that peak-hour downtown cordon volumes of up to 125,000 persons could be accommodated by freeways, BRT, local transit, and arterials under existing capabilities of automobiles and buses. This is ample capacity for the vast majority of U.S. city centers:

> Moreover, as bus technology improves and electronic bus train operation becomes a reality, substantially greater capacities would be achieved. Thus, ultimately, differences between rail and bus transit could become minimal. (*7*)

A 1970 study, *The Potential for Bus Rapid Transit* (*8*), indicated that freeway systems were potentially usable by express buses and, with modification, as exclusive bus lanes or busways. The key factors in evaluating BRT potential were (1) capital costs, (2) operating costs, (3) route configuration, and (4) distribution in the city center and other major activity centers.

In 1973, *NCHRP Report 143: Bus Use of Highways: State of the Art* (*9*) provided a comprehensive review of the state of the art, and, in 1975, *NCHRP Report 155: Bus Use of Highways: Planning and Design Guidelines* (*10*) set forth planning and design guidelines. Using the goal of minimizing total person delay as a guide, the reports suggested ranges in peak-hour bus volumes for bus priority facilities.

A 1972 study, "Bus Rapid Transit Progress in the USA" (*11*), examined and summarized reasons for the implementation of BRT projects in the 1950s and 1960s.

A 1975 study, *Bus Rapid Transit Options for Densely Developed Areas* (*12*), described and evaluated the cost, service, and environmental implications of bus lanes, bus streets, and bus subways. The report showed how various bus priority facilities would be coordinated in the central area and suggested a multidoor articulated bus for BRT operations.

Most of these planning studies focused on the *facility* aspects of BRT, often as an adjunct to urban freeways. Little or no attention was given to the station, service, and image/identity aspects of BRT.

Countervailing Trends

In the middle to late 1970s, the transit planning emphasis shifted away from bus use of streets and highways, BRT, and fully grade-separated metros toward the provision of

HOV lanes and LRT. HOV lanes were perceived as a widely applicable, environmentally positive way of expanding road capacity while reducing single-occupant-vehicle use.

The development of LRT lines gained popularity because of their perceived performance, passenger attractiveness, and image benefits. These aspects were considered to be unattainable by bus transit, but attainable in LRT at costs much lower than those of fully grade-separated metros, such as those in San Francisco; Washington, D.C.; Miami; and Baltimore. LRT tends to be considered more fully in alternative analyses, partially because there is little information available on the potential benefits and costs of BRT.

Recent U.S. Initiatives

FTA has undertaken a BRT initiative in an attempt to encourage local agencies to consider potentially cost-effective BRT alternatives in major investment and alternatives analyses studies. Using Curitiba's BRT system as a model, FTA sponsored a BRT conference in 1998, published major documents highlighting BRT (*13*, *14*), established a BRT Consortium with 17 supporting cities in 1999, and launched a BRT "Demonstration Program" involving 15 cities.

2.B OVERVIEW OF FINDINGS

BRT systems are found today in major cities throughout the world. These systems vary widely in extent, type of treatment, design and operating features, usage, and benefits. Key aspects of the 26 case studies are described in the sections that follow.

2.B.1 Case Study Locations

The locations, urban populations, and key features of the 26 case study cities surveyed are shown in Table A-1 in Appendix A. Most BRT systems are located in large cities, many of which also have rail rapid transit. Nineteen of the systems are found in urban areas of over 700,000, and 16 also have rail transit lines. Nine of the 14 systems in the United States and Canada have a CBD employment that exceeds 85,000.

Twenty-one BRT systems are in revenue service, three are under construction (Boston, Cleveland, and Sydney), and two are under development (Hartford and Eugene).

2.B.2 Reasons for Implementation

The main reasons cited in the case studies for implementing BRT systems were BRT's lower development costs and greater operating flexibility as compared with rail transit. Other reasons were that BRT can be a practical alternative to major highway construction, an integral part of the city's structure, and a catalyst for urban development. Examples of the specific reasons cited for BRT implementation are described below.

United States and Canada

Boston. There has been a need to provide better transit access and more capacity to the growing South Piers redevelopment area and to Logan International Airport. Implementing a BRT system was perceived as providing operational and service benefits rather than merely cost advantages. A limited amount of bus subway construction will provide a one-seat ride to major activity centers such as Logan Airport.

Cleveland. Rail transit on the Euclid Avenue corridor has been proposed for more than a half century, but numerous plans were never realized because of the cost involved and the declining commercial activity in the corridor. Implementing a BRT system was perceived to be more cost-effective and affordable and was seen as a tool for encouraging redevelopment.

Eugene. The proposed BRT system is seen as an environmentally responsive way of alleviating traffic congestion without making costly highway improvements.

Hartford. The busway was found to be a more cost-effective alternative to major freeway reconstruction and more compatible with community-planning goals.

Houston. BRT was able to use Houston's HOV system for running ways. The system, which includes HOV, park-and-ride, and commuter express buses, makes effective use of radial freeway corridors in reducing peak-hour traffic congestion.

Los Angeles. Long delays and cost overruns led to a county referendum prohibiting future subway construction. BRT was seen as a cost-effective alternative to improving bus service in major travel corridors. It was also considered to be a strategy for offsetting a 12% decline in bus speeds in recent years.

Miami. The state of Florida examined cost-effective, affordable public transport uses of an abandoned railroad right-of-way. This led to the decision to build an at-grade busway.

New York City. Morning peak-hour contra-flow bus lanes were viewed as a cost-effective means of increasing the speed of bus travel across the Hudson and East Rivers.

Ottawa. The region's transportation policy gave public transportation projects priority over all forms of road construction or widening. Busway technology was selected because it was cheaper to build and operate. A 1976 study found that a bus-based system could be built for half the capital costs of rail transit and would cost 20% less to operate. It also offered a higher level of service: greater staging flexibility met the capacity requirement of 15,000 passengers per hour in the peak direction and had similar environmental impacts to the rail option (*15*).

Pittsburgh. Busways were politically viable and were easier to implement and more affordable than major highway construction or rail transit. Busways would benefit riders who traveled beyond the limits of the guideways. The Port Authority of Allegheny County was also able to make use of an extensive network of railroad rights-of-way to implement dedicated busways.

Seattle. In the early 1980s, a federal policy of "no new rail starts" required Seattle Metro to explore bus alternatives. A tunnel was selected for its ability to remove buses from downtown streets.

Australia

Adelaide. The Guided Bus system was found to have significantly lower initial costs than a CBD light-rail subway, and it reduced the need for transferring in a low-density corridor. The O-Bahn technology was selected to reduce the cross section of a completely elevated guideway over a riverbed.

Sydney. BRT is being built to provide better transit service to low-density areas with minimum transfer and walk times.

Brisbane. The South East Busway was designed to increase transit level of service in a low-density corridor, to promote transit-oriented development, and to make use of existing HOV lanes on the Southeast Motorway.

Europe

Leeds. The Guided Bus technology provides self-enforcing queue bypasses for buses at congested locations.

Runcorn. The Figure 8 Busway is an integral part of the New Town development.

South America

In South America, there has been an urgent need to improve travel conditions in congested cities with populations that are growing exponentially. There generally have been neither time nor resources to build rail transit. Busways in the center of wide arterial streets emerged as a means of increasing bus performance and capacity.

Bogotá. The TransMilenio four-lane median busway was built after a 3-year period to provide affordable BRT services. It uses physically separated dual median bus lanes to service multiple stations.

Curitiba. The median busway system was found to be more flexible and affordable than rail and was an integral part of the "structural axis" along which development was encouraged.

Quito. Improved public transport became a political imperative; the need for a "clean" (electric trolley bus) system was essential in view of the city's cultural heritage.

The individual case studies included in Appendix B (available on *CRP-CD-31*, which accompanies this volume) provide additional detail regarding the reasons for implementation within each community.

2.B.3 Features of BRT Systems

The main features of the BRT include dedicated running ways; attractive stations; distinctive, easy-to-board vehicles; off-vehicle fare collection; use of ITS technologies; and frequent all-day service.

Table A-2 in Appendix A shows the BRT features listed above for each of the 26 cities analyzed. The table provides a brief overview of the status of BRT around the world. There is a wide range of BRT services and facilities. These different services and facilities reflect specific community needs and resources. The principal features, listed by system and geographic area, are summarized in Table 7.

Over 80% of the systems profiled have some type of exclusive running ways—either a bus-only road or bus lane. More than 75% provide frequent all-day service, and about 67% have "stations" rather than stops. In contrast, only about 40% have distinctive vehicles (in delineation, type, and livery), and roughly 38% feature some type of ITS application. Only five systems (17%) have off-board fare collection.

Three existing systems have all six basic features: Bogotá's TransMilenio, Curitiba's system, and Quito's Trolebus. Rouen has five features, and several other systems have four. Systems

TABLE 7 Number of facilities with specific features

Feature	US / Canada	Australia / Europe	South America	**Total**	**% of Total**
Dedicated Running Ways	13	5	6	24	83
Stations	12	4	3	19	66
Distinctive Vehicles	7	1	3	11	38
Off-Vehicle Fare Collection	2	0	3	5	17
ITS	7	1	3	11	38
Frequent All-Day Service	11	5	6	22	76
Total Systems Surveyed	**17**	**6**	**6**	**29**	**100**

under development in Boston, Cleveland, and Eugene will also have the six BRT elements.

Within the United States and Canada, 13 of 17 systems have dedicated running ways (bus lanes or busways), 12 have stations, 11 have all-day service, 7 feature ITS elements, and only 1 system (Boston's Silver Line) currently has off-board fare collection. Another one is still being planned.

Running Ways

BRT running ways include operations in mixed traffic, median arterial busways, contra-flow freeway bus lanes, normal-flow freeway HOV lanes, busways on separate rights-of-way, and bus tunnels. Descriptions, characteristics, and costs of running ways are given in Table A-3 in Appendix A for each of the 36 individual facilities in the 26 cities surveyed. These running way features are summarized by geographic region in Table 8.

There is considerable variation among BRT facilities from region to region. Independent busways dominate North American and Australian practice, whereas arterial median busways are used throughout South America. Arterial street bus operations are found in two of the three European case studies. Reserved freeway lanes for buses and carpools are found only in the United States.

Bus tunnels exist in Brisbane and Seattle, and one is being developed in downtown Boston. This represents an important advance in BRT facility development, bringing a key running way feature of rail transit to bus operations. It also overcomes the problems associated with street running in congested downtown areas.

Bus-only roads (busways) exist in Miami, Ottawa, Pittsburgh, Runcorn, and Brisbane. Busways are under development in Hartford and Sydney. Figure 2 shows the West Busway in Pittsburgh.

Curb bus lanes traditionally have been the main type of bus priority treatment in North America and Europe, although they were not reported in the case studies. Despite their advantages in bringing buses curbside and their minimum impact on street traffic flow, curb bus lanes are often avoided because of their uncertain availability and conflicts with deliveries. This is certainly the case in South America, where arterial median busways predominate.

Several systems in the United States and Canada (Honolulu, Los Angeles, and Vancouver) operate largely in mixed traffic. In the case of Los Angeles, this is an interim operation, and bus-only lanes will be selectively incorporated in the future.

Running ways are generally radial, extending to or through the city center. However, Vancouver's Broadway-Lougheed Line provides cross-town service and is anchored by the University of British Columbia in the west. Sydney's northwest suburbs busway will be a circumferential facility.

Bus lanes are typically 11 to 12 feet wide. Shoulders are provided along busways where space exists. At busway stations, roadways are typically widened to about 50 feet to allow for express bus or skip-stop passing. Busway envelopes are about 30 to 50 feet between stations. At stations, the total envelope (four travel lanes, plus station-side platforms) can be as wide as 75 feet. Examples of this are the following:

- The New Britain–Hartford Busway will provide a 50-foot envelope at "staggered," or offset, side platform stations.
- The South Miami–Dade Busway provides a 52-foot roadway at stations plus station platforms.
- The Ottawa Transitway provides two 13-foot lanes and 8-foot shoulders. There is a 75-foot envelope at stations.
- Curitiba's arterial median busway has a 23-foot roadway. The overall envelope, including stations and service roads, is 72 to 85 feet wide.

TABLE 8 Types of facility by region

	US/ Canada	Australia	Europe	South America	Total
Arterial Street					
Mixed Traffic	5	-	-	-	5
Queue Bypass	0	-	1 (1)		1
Curb Bus Lanes	0		1 (2)		1
Median Busway	2 (3)			8	10
Freeways/Separate Rights-of-Way					
Contra-flow Lanes	3				3
HOV Lanes	3				3
Busways	7	3 (1)	1		11
Bus Tunnels	2				2
TOTAL	**22**	**3**	**3**	**8**	**36**

(1) Includes O-Bahn and bus tunnel as part of one busway
(2) Optically Guided Bus
(3) Once system includes an electronically guided vehicle

Figure 2. West Busway, Pittsburgh.

Figure 3 shows the typical median busway design used in South American cities.

Stations

BRT station characteristics and features are given in Table A-4 and Table A-5, which are located in Appendix A. Table A-4 shows the spacing, length, bypass capabilities, platform heights, and fare collection practices. Table A-5 describes the reported design features and amenities.

Spacing. Station spacing along freeways and busways ranges upward from about 2,200 feet along Boston's Silver Line to several miles along the Adelaide O-Bahn and the San Bernardino Freeway. The South Miami–Dade Busway has a spacing of almost 2,900 feet; the Pittsburgh busways average 4,200 feet; the Brisbane busway averages 5,540 feet; the Ottawa Transitway system averages 6,900 feet; and the San Bernardino Busway exceeds 21,000 feet.

BRT station spacing along arterial streets ranges upward from about 1,000 feet in Porto Alegre, 1,200 feet in Cleveland, and 1,400 feet in Curitiba to over 4,000 feet along Vancouver's "B" Lines and Los Angeles' Metro Rapid bus service. This spacing, ranging from approximately 125 feet in urban areas to 5,280 feet in suburban areas, is similar to LRT and metro practice.

Locations. Stations are placed curbside when buses operate in mixed traffic, as in Los Angeles and Vancouver. Stations are typically located on the outside of the roadway along arterial medians and busways. However, the Bogotá system, a section of the Quito Trolebus, and Curitiba's "direct" service have center island platforms with commensurate use of left-side doors.

Passing Capabilities. Busways widen from two to four lanes to enable express buses to pass around vehicles making stops. In staggered stop situations, busways typically widen to three lanes. The median arterial busways in South American cities also provide passing lanes for buses; usually, station platforms are offset to minimize the busway envelope, thereby resulting in lane changes (shifts) by buses. Bogotá's median busway has continuous express (passing) lanes. Cleveland will operate express buses on parallel streets, thereby obviating the need for passing lanes at median busway stations.

The Brisbane and Ottawa busways have barriers between opposing directions of travel at stations to prevent at-grade pedestrian crossings, as shown in Figure 4. Pittsburgh has barriers as well as raised curbs with designated crosswalks. Miami merely designates desired crossing locations, as will the planned New Britain–Hartford Busway.

Platform Length. Station platform length varies depending on bus volumes and the lengths of the vehicles operated. Stations typically accommodate two to three buses, although busy stations may accommodate four to five vehicles. Boston's Silver Line, for example, will have 220-foot-long platforms that can simultaneously handle three 60-foot articulated buses. Because of the enormous volumes it carries, Bogotá's TransMilenio busway has bus stations ranging up to 500 feet long.

Platform Height. Most new BRT stations have low platforms because many will be served by low-floor buses. However, three systems in South America—Bogotá's TransMilenio, Quito's Trolebus, and Curitiba's all-stop and "direct" services—provide high platforms to allow level boarding and

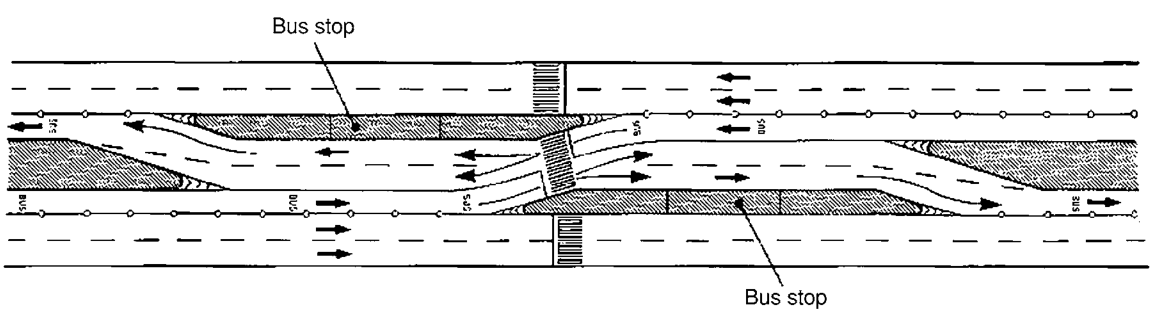


Figure 3. Typical median busway design, South America.

Figure 4. Barrier between opposing directions of travel at Ottawa Transitway station.

Figure 6. Bi-articulated bus median, Curitiba.

alighting of passengers from high-floor vehicles, as shown in Figures 5 and 6. Guided vehicles such as the Irisbus Civis vehicle used in Rouen or buses with drop-down bridges, such as those used in Bogotá, Quito, and Curitiba, are required for floor-to-platform boarding and alighting.

Fare Collection. Bogotá, Curitiba, and Quito have off-vehicle fare collection in conjunction with their high-platform stations, similar to metrorail systems. The stations function essentially like those for rail rapid-transit lines. Prepayment, along with multidoor use of buses, reduces dwell times; this is apparent in the reduction of 20 seconds per stop in Curitiba. In Rouen, the barrier-free honor fare system, similar to that used in the city's LRT system, facilitates multiple-door boarding. In other cities with high BRT passenger volumes (e.g., Ottawa and Pittsburgh), the use of fare passes allows at least two-stream boarding through front and back doors.

Design Features. Stations in the case study systems provide a broad spectrum of features and amenities depending on location, climate, type of facility, and available space. Some are simple, attractive canopies, as can be seen along the South Miami–Dade Busway or Los Angeles's Metro Rapid lines, shown in Figure 7. Others, such as those along Brisbane's South East Busway, provide distinct and architecturally distinguished designs, as well as a full range of pedestrian facilities and conveniences, as shown in Figure 8. The "high-platform" stations in Bogotá, Curitiba, and Quito contain extensive space for fare payment. Curitiba's tube stations have become an internationally recognized symbol. The Los Angeles Metro Rapid bus stations feature real-time bus arrival information.

Overhead pedestrian walks connect opposite sides of stations in Brisbane and Ottawa, as well as busy stations in Pittsburgh. In some situations, access to both platforms is provided from roadway crossings over the busway.

Vehicles

BRT vehicles range from conventional buses to distinctive, dedicated BRT vehicles. Key characteristics of BRT vehicles for selected systems are shown in Table A-6 in Appendix A.

Figure 5. Trolebus station, Quito.

Figure 7. Los Angeles Metro Rapid bus station.

Figure 8. South East Busway station, Brisbane.

Body Style. Vehicle body styles include the standard (40-foot) bus, articulated (60-foot) buses, and, in Curitiba, bi-articulated buses. Some double-deck buses operate in Leeds, and Houston's BRT service uses over-the-road intercity coaches. It is important to note that almost every city cited in the United States and Canada, except Los Angeles and Vancouver, operates or will operate articulated vehicles. Figure 9 shows the dual-mode articulated bus that will be used in Boston's South Pier Transitway. Rouen, Boston, and Cleveland operate or plan to operate special BRT vehicles rather than conventional buses.

Propulsion. Standard diesel buses predominate; however, a trend in North America is to use "clean" vehicles such as CNG or hybrid diesel-electric vehicles (as in Los Angeles and Cleveland). Seattle and Boston operate or will operate dual-mode electric trolley and diesel or CNG buses. The Irisbus Civis vehicle used in Rouen, France, is a "new design" diesel or CNG electric vehicle with train-like features and the ability to be guided. This vehicle is shown in Figure 10.

Figure 9. Dual-mode articulated bus.

Figure 10. Irisbus Civis vehicle used in Rouen.

Floor Height. An increasing number of systems operate low-floor vehicles to make passenger boarding and alighting easier. Buses in Bogotá, Curitiba, and Quito have high-platform boarding and alighting. Although these vehicles reduce passenger service times, their operation is limited to the BRT lines with high-platform stations. This dramatically reduces their operating flexibility.

Door Arrangements. The need for better door arrangements on buses used in BRT service is increasingly recognized. Existing door arrangements have been a major constraint to shortening dwell times on many North American bus systems. Many articulated buses have three double-stream doors and one single-stream door. The bi-articulated buses used in Curitiba have five sets of doors. The rail-like articulated Irisbus Civis vehicle has four doors.

Doors are generally located on the right side for North American and French systems and on the left side for buses operating in Australia and Great Britain, although left-hand doors are available from many manufacturers (e.g., Irisbus and Gillig) to support center platform stations. The "direct buses" in Curitiba, which operate along one-way arterials, have left-side doors, as do buses operating in Bogotá. Some of the buses operating in Sao Paulo have doors on both sides to better serve various platform arrangements.

Design Features. Several BRT systems have dedicated vehicles with special identity and livery. Bogotá, Curitiba, and Los Angeles use red buses for their BRT services. Honolulu, Quito, and Vancouver have distinctively striped buses. Rouen's Irisbus Civis vehicles and Bogotá's TransMilenio buses have modernistic rail-like styling and a futuristic appearance and could serve as prototypes for future BRT vehicle designs. Rouen's Irisbus Civis buses have a minimum aisle width of 34 inches end to end.

ITS

Selected applications of ITS technologies used in BRT operations are set forth in Table A-7 in Appendix A. The applications shown cover (1) automatic vehicle location (AVL) systems; (2) passenger information systems (e.g., automated station announcements on vehicles, real-time information at stations); and (3) traffic signal preference/priorities.

BRT systems using AVL systems include Boston (under construction), Hartford (under development), Los Angeles, Vancouver, Brisbane, Sydney (proposed), and Bogotá.

Systems with passenger information systems include Boston (under construction), Hartford (under development), Ottawa, Pittsburgh (some buses), Vancouver, Brisbane, Los Angeles's Metro Rapid bus, and Curitiba.

Systems having traffic signal timing priorities or special bus phases include Cleveland (under development), Los Angeles, Vancouver, and Rouen. The Metro Rapid lines in Los Angeles, for example, can get up to 10 seconds of additional green time when buses arrive at a signalized intersection. However, at major crossroads, advancing or extending the green time for buses can take place only every other cycle. Bus signal preemption along South Miami–Dade Busway was removed because of increases in accidents. The Brazilian cities of Porto Alegre and Sao Paulo have bus platoon dispatching systems (Commonor) that are used to increase bus and passenger throughput.

Service Patterns

The types of BRT service provided in the various BRT case studies are shown in Table A-8 in Appendix A. The specific patterns reflect the types of running ways and vehicles utilized. Most systems provide express or limited-stop services laid over an all-stop (or local) service that operates like an LRT line. Some also have feeder bus lines that serve selected stations.

Busways—either along separate rights-of-way or within street medians—can have basic "all-stop" service with an overlay of express operations during peak periods. In a few cases, such as Cleveland and Curitiba, the express service is or will be provided along nearby parallel streets. BRT operations in mixed traffic—as in Honolulu, Los Angeles, New York City, and Vancouver—provide limited-stop service. Local bus service is also operated along the streets, as part of the normal transit service. Rouen's BRT system also provides limited-stop service along arterial streets.

The bus tunnels in Boston and Seattle are located in downtown areas. All buses make all stops in the tunnels.

The "guided buses" in Leeds and Eugene essentially provide all-stop service. Quito's Trolebus service also stops at all stations.

Buses operating in New York City's reverse-flow expressway bus lanes run express and do not make intermediate stops. Buses using median expressway lanes in Charlotte's and Houston's HOV lanes also operate nonstop; there are no intermediate stops. However, in Houston, there are a number of routes that exit the HOV lanes on dedicated bus ramps, enter transit centers or park-and-ride lots to drop off or pick up passengers.

In most systems, the BRT service extends beyond the limits of busways or bus lanes. This flexibility is an important advantage of BRT as compared with rail transit. However, three BRT systems in South America operate only within the limits of the special running way, mainly because of door arrangements, station platform heights, and/or propulsion systems. These systems, including Bogotá's TransMilenio, Curitiba's median bus service, and Quito's Trolebus, actually function as though they were rail rapid-transit lines.

2.B.4 Performance

Performance characteristics of the existing BRT systems, as measured by passengers carried and travel speeds, are shown in Table A-9 in Appendix A. Performance varies widely, reflecting factors such as facility location, size of the urban area, and type of facility (e.g., off-street or arterial).

Weekday Riders

The weekday ridership reported for existing systems in North America and Australia ranged from about 1,000 riders in Charlotte to 40,000 or more in Los Angeles, Seattle, and Adelaide. Specific ridership figures are shown in Table 9.

Daily ridership in South American cities is substantially higher. Reported values for specific facilities include 150,000 riders per day in Quito, 230,000 in Sao Paulo, and about 600,000 in Bogotá. Reported system riders exceed 1,000,000 in Belo Horizonte, Curitiba, and Porto Alegre.

Peak-Hour Bus Flows

Where there are no intermediate stops, peak-hour, peak-direction bus flows on dedicated freeway lanes can exceed

TABLE 9 Ridership figures for selected BRT systems

Bus Subways	Seattle	46,000
Busways	Ottawa	200,000
	Brisbane	60,000
	Pittsburgh	48,000
	Adelaide	30,000
	San Bernardino (Los Angeles)	18,000
	Miami	12,000
	Harbor (Los Angeles)	9,400
	Charlotte	1,000
Arterial Streets	Wilshire (Los Angeles)	55,000
	Vancouver	14,000–24,000
	Ventura (Los Angeles)	10,000

650 buses per hour (e.g., on the New Jersey approach to the Lincoln Tunnel and the Port Authority of New York/New Jersey Midtown Bus Terminal.) The Ottawa Transitway system reports bus volumes of 180 to 200 buses per hour along downtown bus lanes. These volumes result from high use of fare passes, an honor fare system on the Busway All-Stop routes, and use of multidoor articulated buses. Over 140 buses per hour use the busiest section of Brisbane's South East Busway.

Peak-hour flows of over 100 buses per hour are found in the contra-flow bus lanes on New York City's Long Island Expressway and Gowanus Expressway. Most other BRT facilities in the United States and Australia have less than 100 buses per hour. Flows of about 50 to 70 buses per hour are typical.

The South American arterial median bus lanes that have passing capabilities at stations carry as many as 300 buses per hour one way at the maximum load point.

Peak-Hour, Peak-Direction Riders

Peak-hour passenger volumes carried past the maximum load points exceed 25,000 on the approach to the Lincoln Tunnel in New York, on Bogotá's TransMilenio four-lane busway, and along the Farrapos Busway in Porto Alegre. Peak-hour passenger volumes approach 20,000 on median busways in Sao Paulo and Porto Alegre. Ridership in Quito, Ottawa, and Curitiba is in the 8,000–12,000 range. Brisbane's South East Busway carries 9,500 people one way in approximately 150 buses during the peak hour. Its capacity has been estimated at 11,000 persons per hour. The ridership seen in the international case studies equals or exceeds the number of LRT and metro passengers carried in most U.S. and Canadian cities.

Speeds

BRT operating speeds depend upon the type of running way and service pattern. Where buses run nonstop on reserved freeway lanes, revenue speeds of 40 to 50 miles per hour are common. When the service patterns include stops on reserved or dedicated lanes, buses generally average 20 to 30 miles per hour, depending on top spacing and dwell times. These speeds are comparable with LRT speeds for the same type of operating environment. The slower speeds recorded along Miami's busway reflect stops and traffic signal delays at signalized intersections along the busway.

Average speeds for BRT operations along arterial streets in the United States and Canada range from 8 to 14 miles per hour in New York City to 15 miles per hour along Wilshire Boulevard and 19 miles per hour along Ventura Boulevard in Los Angeles.

"Express" operations along Curitiba's one-way streets and Bogotá's TransMilenio busway are approximately 19 miles per hour. Buses making all stops along median busways in South America average 11 to 14 miles per hour. These speeds are low when compared with BRT operations in the United States and Canada. However they represent dramatic improvements over local bus speeds and are often faster than automobile speeds.

2.B.5 Benefits of BRT

BRT systems have achieved important benefits in terms of travel time savings, increased ridership, land development impacts, and improved safety.

Travel Time Savings

Reported travel time savings resulting from BRT operations are shown in Table A-10 in Appendix A. These savings are shown as the percent change in speeds, the total time saved in minutes, and the minutes saved per mile of travel.

Travel time reductions resulting from the introduction of BRT services have sometimes exceeded 40%. Bus operations in exclusive freeway lanes or busways have achieved travel time savings of 47% in Houston, 44% in Pittsburgh, 38% in Los Angeles, and 32% in Adelaide compared with local bus routes. Seattle's bus tunnel has achieved a 33% reduction in bus travel times for the CBD portion of bus routes.

BRT service along arterials has achieved travel time savings of 23% to 28% in Los Angeles, 29% in Porto Alegre, and 32% in Bogotá compared with the fastest alternative bus services. The time savings in Los Angeles are impressive in that buses operate in mixed traffic. These time savings have been achieved by increasing the spacing between stops and by providing up to 10 seconds of additional green time at signalized intersections using a signal priority system.

Total time savings range from 5 minutes at Seattle's bus tunnel to over 20 minutes along Pittsburgh's East and West

Busways. Most facilities achieve time savings of 2 to 3 minutes per mile.

Busways and reserved bus lanes on freeways that bypass traffic backup on approaches to river crossings save up to 7.5 minutes per mile. Busways on partially grade-separated rights-of-way generally save 2 to 3 minutes per mile over the previous bus service. BRT lines on arterial streets typically save 1 to 2 minutes per mile. The savings are greatest where the previous bus routes experienced major congestion.

Ridership Increases

Reported increases in bus riders are given in Table A-11 in Appendix A. The increases reflect the provision of expanded transit service, reduced travel times, improved facility identity, and overall population growth. Collectively, the increases clearly demonstrate that BRT can attract and retain new, even discretionary, riders.

Some evidence suggests that many of the new riders were previously motorists and that improved bus service results in more frequent travel. In Houston, for example, up to 30% of the riders were new riders, and up to 72% were diverted from automobiles. In Los Angeles, the Metro Rapid bus service, which operates in mixed traffic, had about a 33% increase in riders. The increase was made up of new riders, riders diverted from other corridors, and people who rode transit more often. In Vancouver, 20% of new riders previously used automobiles, 5% represented new trips, and 75% were diverted from other bus lines.

Adelaide's Guided Busway reported a 76% gain in ridership at a time when overall system ridership declined by 28%. Brisbane's South East Busway reported over a 40% gain in riders during the first 6 months of service and a reduction of 375,000 automobile trips annually.

Operating and Environmental Benefits

The travel time savings associated with buses operating on their own rights-of-way have also achieved operating costs and safety and environmental benefits, as shown in Table 10. All cost savings are reported in U.S. dollars.

The Ottawa Transitway requires 150 fewer buses than if the Transitway system did not exist, resulting in savings of roughly $49 million in vehicle costs and $19 million in annual operating costs.

Seattle's bus tunnel has reduced surface street bus volumes by 20%. Buses using the tunnel also had 40% fewer accidents than in mixed-traffic operations.

Bogotá's TransMilenio busway had 93% fewer fatalities. In addition, a 40% drop in pollutants was recorded during the first 5 months of operation.

Curitiba uses 30% less fuel per capita for transportation than other major Brazilian cities. This has been attributed in part to the success of the BRT system.

Land Development Benefits

Like other rapid rail transit modes, BRT stations can provide a focal point for transit-oriented development. Reported land development benefits and other benefits are shown in Table 10. Ottawa reported over $675 million in new construc-

TABLE 10 Benefits, selected BRT systems

SYSTEM	LAND DEVELOPMENT BENEFITS
Pittsburgh East Busway	59 new developments within a 1500-ft radius of station. $302 million in land development benefits, of which $275 million was new construction. 80% is clustered at station.
Ottawa Transitway System	$1 billion in Canadian dollars ($C) in new construction at Transitway stations.
Adelaide Guided Busway	Tea Tree Gully area is becoming an urban village.
Brisbane South East Busway	Up to 20% gain in property values near Busway. Property values in areas within 6 miles of station grew 2 to 3 times faster than those at greater distances.
	OTHER BENEFITS
Ottawa Transitway	150 fewer buses, with $58 million ($C) savings in vehicle costs and $28 million ($C) in operating costs.
Seattle Bus Tunnel	20% reduction in surface street bus volumes. 40% fewer accidents on tunnel bus routes.
Bogotá TransMilenio Median Busway	93% fewer fatalities. 40% drop in pollutants.
Curitiba Median Busway	30% less fuel consumption per capita.

tion around Transitway stations. Pittsburgh reported $302 million in new or improved developments along the East Busway stations. Values of property located near Brisbane's South East Busway grew two to three times as fast as the values of property located at greater distances. These impacts are similar to those experienced along rail transit lines.

In the cases of several of the BRT systems studied, local governments implemented land use planning policies that encouraged development near BRT facilities. In the Ottawa-Carleton region, major developments such as regional shopping centers are required to locate near the Transitway. In Curitiba, the arterial median busways are integral parts of the structural axes along which high-density development has been fostered.

2.B.6 Costs

Costs for BRT systems vary widely depending on the BRT elements being implemented (e.g., running ways, vehicles, etc.) and the location, type, and complexity of construction. Development costs for the BRT systems in the case studies are shown in Table A-12 in Appendix A. For the implemented systems, these costs reflect those incurred at time of construction. The costs per mile of facility are also shown. A comparison of the costs shows the following:

- Costs for bus tunnels range from about $200 to $300 million per mile, including stations.
- Costs for busways on their own rights-of-way display a wide range, depending upon the year they were built and ease of construction. The values cited range from about $6 to $7 million in Los Angeles, Miami, and Pittsburgh (South Busway) to about $20 million per mile for the East Busway in Pittsburgh and the recently completed South East Busway in Brisbane. The high cost of Pittsburgh's West Busway—about $53 million per mile—was due to the hilly terrain traversed, a major tunnel rehabilitation, and an expensive freeway interchange at the outer terminus of the busway.
- Costs for arterial street median busways have been reported as about $1.5 million per mile in Curitiba, $5 to $8 million per mile in Bogotá and Quito, and an estimated $29 million per mile in Cleveland.
- Costs for mixed-traffic operation have generally been less than costs for BRT systems with dedicated running ways. The costs reported for guided bus systems include $2.4 million per mile of guideway in Leeds, $7 million per mile in Rouen, and less than $8 million per mile expected in Las Vegas.

Information on busway maintenance costs was only available for Pittsburgh's East Busway. These costs averaged $110,000 per mile per year for 7 miles.

Operating costs for BRT service are influenced by wage rates and work rules, fuel and electricity costs, operating speeds, and ridership. Operating costs for Pittsburgh's East Busway and South Busway (1989) averaged $0.52 per passenger trip. Costs per trip for light rail lines in Buffalo, Pittsburgh, Portland, Sacramento, and San Diego averaged $1.31; the cost range was from $0.97 (San Diego) to $1.68 (Sacramento). These comparisons suggest that BRT can cost less per passenger trip and per mile than LRT, depending on the situation (*16*).

CHAPTER **3**

IMPLICATIONS AND LESSONS LEARNED

The last several decades have seen a transition from bus lanes and prioritization treatments to full-featured BRT. Thirty years ago the emphasis was on curb bus lanes, freeway ramp queue bypasses, and “physical elements.” BRT packages now include extensive busway systems, median bus lanes, and special-purpose BRT vehicles and focus on service patterns, amenities, image, and identity.

The BRT systems examined in the case studies generally have several of the key BRT elements including running ways, attractive stations, distinctive vehicles, off-vehicle fare collection, application of ITS technologies, and a clear service pattern. A few systems have or will have all of these features. These systems include Boston, Cleveland, and Eugene (which are under development in the United States); Bogotá, Curitiba, and Quito (which operate in South America); Brisbane (which is operating in Australia); and Ottawa (which is operating in Canada).

3.A LESSONS LEARNED

Each urban area has unique circumstances that influence BRT markets, service patterns, viability, design, and operations. Within this context, several key lessons, implications, and directions have emerged from the case studies. Many of these lessons can also apply to rapid-transit planning and development in general. The lessons learned are organized as follows:

- Planning and Implementation Process,
- System Concepts and Packaging,
- Running Ways,
- Stations,
- Vehicles,
- Fare Collection,
- ITS Applications,
- Service Plan and Operations,
- Traffic-Transit Integration, and
- Performance.

3.A.1 Planning and Implementation Process

BRT system development should be an outgrowth of a planning and project-development process that stresses problem solving and addresses demonstrated needs. A General Accounting Office report states that

> the future of Bus Rapid Transit, especially in the United States rests largely with the willingness of communities to consider it as they explore transit options to address their specific situations. Such decisions are difficult and are made on a case-by-case basis considering a variety of factors, including cost, ridership, environmental impacts, and community needs and attitudes (*17*).

Community and Agency Support

Early and continuous community support for an open planning process that objectively considers BRT among other options is essential. It is necessary to maintain public dialogue and to recognize and respond to community concerns at each major step in the planning process.

Because successful BRT implementation may require participation of transit operators and highway agencies, all prospective actors should be a formal part of the planning effort. Participants also may include representatives of private-sector transit operators as well as the police departments that may be responsible for transit facility enforcement, safety, and security.

Planning for BRT should be approached from the perspectives of the communities and agencies involved. The costs and benefits of BRT, along with other alternatives, should be clearly described. Like other rapid-transit systems, a BRT alternative should be reasonable in terms of usage, travel times saved, costs, development benefits, and impacts to general traffic.

So that BRT is considered in its proper place along with other modes, decision makers and the general community must understand the nature of BRT and its potential. BRT’s potential performance, attractiveness to customers and developers, operating flexibility, capacities, and costs should be clearly identified in alternatives analyses that objectively consider other options as well.

A BRT system often can be more cost-effective and provide greater operating flexibility than rail transit. It also can be a cost-effective alternative to extending rail transit through low-density residential areas, as in Miami. Because of these potential advantages, BRT should be carefully considered as options are explored and assessed during the planning process.

Agency Coordination

State, regional, and local cooperation is important in developing and implementing BRT projects. Transit planners, traffic engineers, and urban planners must work together to address the many issues related to BRT systems. In the United States, metropolitan planning agencies and state DOTs should be major participants. In Hartford, Miami, and Pittsburgh, state DOTs played major roles in busway development.

Political commitment and appropriate institutional arrangements are essential. Fragmented responsibilities among multiple agencies should be avoided. In Quito, for example, the city created a single agency with adequate powers to control and improve public transportation.

Incremental Development

BRT lends itself to incremental development. In many cases, it may be useful to identify a BRT segment for immediate, early implementation. Early action is essential to retain community support and continuity of public agency staff. This will demonstrate BRT's potential benefits as soon as possible to riders, decision makers, and the public at relatively little cost while still enabling system expansion and possible future upgrading (e.g., to more technologically advanced vehicles). Examples of staging opportunities include the following:

- The initial segment, for example, could include curb bus lanes that may be upgraded to busways in the future. A BRT line can also serve as a means of establishing the transit market for a possible future rail line.
- BRT service along a busway does not preclude ultimate conversions to rail transit when and if such a conversion is warranted by ridership or other considerations.
- Ottawa's approach of providing broader coverage through "outside-in" priorities has proven more cost-effective in attracting riders and influencing travel choices than has the traditional concentration on shorter, more costly, inner-city sections.

Parking Policy

BRT system performance can be influenced by parking supply and demand. Parking policies are important to BRT and all rapid-transit modes in two important respects:

1. Ample parking should be provided along busways, especially at outlying stations. Parking supply can expand the catchment area and reduce the need for extensive feeder bus service in low-density residential areas. Care must be given so that extensive parking does not preclude joint development.
2. In several existing systems, park-and-ride facilities are provided in limited supply along many existing busways, and several of the planned facilities (e.g., the Pittsburgh busway expansion and Hartford's facility) will include parking at key stations. The proper level of parking supply along BRT lines or systems is an area that requires further analysis.

Parking for those who choose to drive to work should be limited where major BRT investments are planned. This is already in effect in Boston and Ottawa.

Land Use Coordination and Economic Development Effects

BRT and land use planning for station areas should be integrated as early as possible and done concurrently. A "transit overlay" zoning district may be an appropriate strategy for encouraging transit-oriented development. Density bonuses may also promote mixed residential and commercial developments near transit stations.

Close working relationships with major developments may be necessary to address issues of building orientation, connections to stations, and setbacks. Cleveland, for example, is working with the Cleveland Clinic to achieve desired building setbacks and orientation.

Adelaide, Brisbane, Ottawa, Pittsburgh, and Curitiba have demonstrated that BRT can achieve land use and economic development benefits similar to those produced by rail transit. However, achieving these benefits requires coordination from the beginning. In countries where land use planning is stronger than in the United States, environmental preservation and focused commercial development are frequently integral parts of BRT system development.

Although integrated land use and transport is usually difficult to achieve, a long-term view should be taken. First, transit supportive actions should be encouraged in BRT corridors. Additionally, the coordination of new developments with BRT planning can be mutually beneficial.

BRT Markets

BRT has been mainly utilized in larger urban areas, either as an alternative or complement to rail transit. The case studies indicate that most urban areas with BRT have more than a million residents and CBD employment of at least 75,000. In these areas, sufficient ridership demand enables frequent service as part of a full-featured BRT application in at least one corridor.

BRT works well in physically constrained environments where hills, tunnels, and water crossings result in frequent congestion and make freeway construction costly, difficult, and impractical.

BRT systems should serve demonstrated transit markets. The 33% ridership gain along Wilshire Boulevard—perhaps the heaviest bus corridor in Los Angeles—indicates that it is beneficial to penetrate major catchment areas rather than to skirt them.

It is essential to match rights-of-way with transit markets. The presence of an exclusive right-of-way is not necessarily sufficient to ensure the effectiveness of BRT services, especially when the right-of-way is removed from major markets, or the stations are inaccessible to transferring passengers or pedestrians (as seen with the Harbor Transitway in Los Angeles).

3.A.2 System Concepts and Packaging

BRT should include as many attributes of any high-quality, high-performance rapid-transit system as possible. These attributes can be specially adapted to the unique characteristics of BRT, especially its service and implementation flexibility. A successful BRT application will have all the key attributes of rail transit—segregated and prioritized rights-of-way; attractive stations with passenger amenities; off-vehicle fare collection; and attractive, multidoor vehicles. Service patterns should be clear, service should be frequent and fast, and bus stops should be spaced widely apart.

To optimize the potential benefits of BRT, there should be a focus on service, station and vehicle amenities, system integration, and development of a coherent image. These attributes can be more significant than the potential cost advantages of BRT. In Boston, for example, the Silver Line will provide one-seat rides to major destinations far beyond the extent of the bus guideway.

A successful BRT project that achieves its full potential calls for more than merely providing a bus-only lane, queue bypass, or even a dedicated busway. It requires the incorporation and integration of the entire range of rapid-transit elements and the development of a unique system image and identity. Service simplicity, frequency, image, and identity are essential.

Although providing bus lanes, signal priority, or queue bypasses may be effective in reducing congestion, these provisions do not necessarily constitute BRT, even where there is express and limited-stop bus service and other BRT features. However, use of BRT running ways should be mainly limited to buses.

BRT systems, like any rapid-transit system, should be designed to be as cost-effective as possible. However, transportation planners should not "cut corners" by eliminating key system elements and their integration as a means of reducing cost.

System identity and image are essential because they provide the customer with information on where to access the system and routing. These features alone can increase ridership in a competitive, consumer-oriented society. The image or identity of the BRT system should be emphasized in the design of all BRT system physical elements including stations, vehicles, running ways, and graphics.

The Ottawa, Brisbane, and Curitiba case studies demonstrate that the image of BRT can be enhanced by station design features, dedicated BRT vehicles, more effective fare collection methods, and marketing approaches that simplify use of the system and give it a clear identity. For example, to clearly identify BRT routes, Rouen and other French cities color their bus lanes, as shown in Figure 11. Ireland and New Zealand cities use green pavement, whereas cities in Brazil and Japan use yellow pavement.

3.A.3 Running Ways

BRT service operates successfully in mixed traffic, as seen in Los Angeles. HOV facilities can also be effective in certain markets. Bus lanes have been used to reduce traffic delays in congested areas such as New York, Pittsburgh, and Los Angeles. The use of separate rights-of-way can enhance speed, reliability, safety, and identity, as seen in Ottawa, Brisbane, and Pittsburgh. Mechanical, electronic, and optical guidance systems are used in several cities (e.g., Adelaide and Rouen) to reduce rights-of-way or to improve bus operations.

Busways

Rights-of-way for busways should be purchased or reserved as early as possible. Alignments that may pose barriers to

Figure 11. Bus lanes in Rouen.

implementation should be avoided. However, the right-of-way should adequately serve its market. It may be desirable to purchase or preserve rights-of-way in anticipation of future BRT projects.

Railroad and freeway rights-of-way offer opportunities for relatively easy land acquisition, minimum property impacts, and low development costs, as described in the Brisbane, Miami, and Pittsburgh case studies. However, the availability of the right-of-way should be balanced with proximity and access to markets. Rights-of-way located along railroad or freeway corridors may generate little walk-on traffic, limited opportunities for new land development, and complex negotiations. Moreover, when the railroad right-of-way is close to a parallel major arterial road, as in Miami, there are additional challenges associated with the coordination of traffic controls.

Busways can be provided as integral parts of new town development, as in Runcorn, or as an access framework for areas that are under development.

Bus tunnels have potential in downtown areas where congestion is frequent, bus volumes are high, and street space is limited, as in Boston, Brisbane, and Seattle. Bus tunnels can save buses 2 to 3 minutes per mile, as compared with local operations in mixed traffic.

Where BRT commuter express service operates on an HOV facility, it should have its own direct access and egress ramps to and from stations. Such services should also feature intermodal terminals, as they do in Houston. Requiring BRT vehicles to weave across multiple lanes of general traffic to get to median HOV lanes should be avoided.

Arterial Street Bus Lanes and Median Busways

The placement and design of bus lanes and median busways on streets and roads should take into account the diverse needs of buses, motorists, delivery vehicles, pedestrians, and turning and cross traffic.

Curb bus lanes have the advantages of good pedestrian access, curbside passenger boarding and alighting, and the ability to be installed on most roadways. However, they pose problems with competition for curb space, enforceability, and lack of identity. Curb lanes are widely used to expedite bus flow and to feed or distribute busway vehicles (e.g., Pittsburgh and Ottawa). The New York City case study indicates that extensive systems of curb bus lanes can be implemented in densely developed central areas to expedite bus flow. In such cases, effective enforcement is essential.

Median busways are widely used throughout South America and are or will be used for BRT systems in Cleveland, Eugene, and Vancouver. They are usually physically separated from adjacent traffic lanes by narrow islands.

The positive aspects of BRT facilities in arterial street medians are identity, the avoidance of interference with access to adjacent land uses, and minimum side impedance. The negative aspects are interference with left turns and potential pedestrian access problems.

Arterial median busways are freed from the effects of property access and goods delivery, and they are less likely to be used by other traffic. They provide a clear sense of BRT identity, much like the streetcar lines did a half century ago. However, they require wide curb-to-curb widths to accommodate the busway running ways, stations, and general traffic requirements. The South American case studies indicate that a high-capacity facility with station bypass lanes can be introduced into an existing arterial right-of-way that is at least 75 feet wide.

Facility design must allow safe pedestrian access to and from bus stops and suitable accommodations for left turns. Traffic signal phases for left turns should minimize the likelihood of same-direction bus-car accidents, which is a common occurrence with several LRT lines. Where there are nearby parallel one-way streets, left turns could be prohibited along busways and indirect routings could be provided.

The main constraints for providing dedicated busways in U.S and Canadian cities are finding suitably wide rights-of-way and the costs associated with right-of-way acquisition.

Speeds

Limited-stop BRT operations on city streets can achieve overall speeds between 15 and 20 miles per hour. BRT operations on busways can achieve speeds of 30 miles per hour with stops and up to 55 miles per hour nonstop, with overall route revenue speeds of 25 to 35 miles per hour. Therefore, to provide speeds that are competitive with driving an automobile, a BRT should operate off-street on busways, with wide spacing between stations wherever possible.

3.A.4 Stations

Stations are a key element in providing adequate capacity along a BRT line. They are also a critical element in achieving bus system identity and image. Station design should provide sufficient capacity for the likely peak-hour bus flows. Generally, several loading positions are provided. Stations along busways often provide passing lanes to enable express buses to pass stopped vehicles. Sometimes fences are used to preclude random crossings by pedestrians.

Safe pedestrian and automobile access to stations, as well as to feeder bus services, are critical in achieving ridership objectives. Context-sensitive design and community involvement will both ease implementation and encourage transit-oriented land use. Stations can be attractively and distinctively designed whether they are simple curbside shelters or busway structures. Major BRT stations should have as many amenities as possible, including those normally found at heavy rail and commuter rail stations.

High-platform stations with pre-payment of fares are used in Bogotá, Curitiba, and Quito. These designs reduce passenger service times, but they are not as common in the U.S. and Canadian environments where BRT service extends beyond the busway limits. Station capacity is enhanced when fares are collected off board and multiple-stream boarding is provided through multiple doors.

3.A.5 Vehicles

Greater attention needs to be given to vehicle design and identity. Several manufacturers, such as Irisbus Civis, Bombardier, and Neoplan, are starting to recognize this need by producing specialized BRT vehicles. Key considerations to vehicle design are sufficient capacity, ease of passenger entry and exit, improved comfort, adequate circulation space, and reduced noise and emissions. Vehicles must clearly convey transit system identity and image by color, markings, and/or vehicle design. High-capacity (e.g., articulated) buses on heavily traveled routes can achieve an optimum balance between frequent bus service for passengers and efficient bus operations without resulting in bus-on-bus congestion at stops.

Examples of BRT vehicles that are (or will be) in service include Boston's multidoor articulated dual-mode bus, Bogotá's TransMilenio articulated bus, Curitiba's bi-articulated bus, and the optically guided Irisbus Civis vehicles used in Rouen.

Fleets of vehicles dedicated to BRT service are desirable. However, vehicles should be configured to meet specific BRT applications because one size may not always fit all conditions or needs. For example, Miami operates vehicles of differing sizes on its busway. New bus technologies should be carefully tested before being placed in revenue service.

3.A.6 Fare Collection

Fare collection procedures are normally based on specific demand elements of a BRT system. On-board fare collection may be desirable to minimize operating costs in many environments, especially at low-volume stations or during certain times of the day. Off-vehicle fare collection is desirable at major boarding points, especially during peak periods, to reduce passenger service times, station dwell times, and bus travel times. Many of the BRT systems examined in the case studies require improvements in fare collection procedures.

Possible strategies include off-vehicle fare collection at selected stations or the use of passes and possibly honor fare systems similar to those used on LRT systems. ITS and smart card technology applied at multiple doors may be the key to allowing simultaneous on-board fare payment and multiple-door boarding without increasing revenue shrinkage. On-board magnetic card readers for fare payment may actually increase dwell times more than requiring exact change or token payment.

3.A.7 ITS Applications

ITS applications can greatly enhance the success of BRT systems. At relatively modest costs, ITS applications may replace some of the functions provided by expensive and difficult-to-maintain physical infrastructure or other types of rapid transit. ITS applications can be used to convey passenger information in a variety of venues, to monitor or control bus operations, to provide priority at signalized intersections, to enhance safety and security on board vehicles and at stations, and even to provide guidance for BRT vehicles.

In places where ITS has been applied most successfully to BRT, such as in Los Angeles, ITS elements have been part of a geographically larger, functionally comprehensive ITS system.

3.A.8 Service Plan and Operations

The service plan should be designed for the specific needs of the BRT environment and may include a variety of services. A primary advantage of BRT is the ability to provide point-to-point one-seat rides because of the relatively small size of the basic service unit compared with that of rail rapid-transit systems. Providing point-to-point service must be balanced against the need for easy-to-understand, high-frequency service throughout the day.

As ridership increases, it may become necessary to increase trunk line service frequency and to convert some overlay services to feeders or shuttles. BRT should minimize transfers to attract choice riders. Where transfers are necessary, they should take place in station facilities that are attractive, that offer amenities, and that are designed to minimize walking distances and level changes.

Service frequencies should be tailored to market demands. When frequent and reliable transit services are desired, maximum headways of 10 minutes in peak periods and 15 minutes in non-peak periods will minimize the need for set passenger schedules on BRT all-stop service routes. Where two services operate on the same BRT line (e.g., limited-stop BRT and local bus operations, or BRT express and all stop), it is preferable to have minimum combined frequencies of about 5 minutes in the peak period and 7.5 minutes in the base period to minimize the need for set passenger schedules.

The maximum number of buses operating during peak hours should be governed by (1) meeting ridership demands, (2) minimizing bus congestion, (3) operating costs, and (4) operational constraints. This might require operating fewer buses than is physically possible. Curitiba, for example, provides peak service on 90-second headways for its median busway all-stop service, whereas direct express buses operate on parallel streets. Headway-based schedules work well where buses operate at close intervals.

Public regulation of BRT operations might be needed where services are contracted or privately operated. Private-sector operation under public supervision has proven successful in Curitiba, where the combination of public–private sector initiatives has resulted in an efficient, high-quality bus service.

BRT service can extend beyond the limits of dedicated guideways if reliable, high-speed operations can be sustained. Outlying sections of BRT lines, and in some cases CBD distribution, can use existing general traffic roads and streets. These streets, which can include HOV lanes, should be suitably modified through graphics, signage, and pavement markings to improve BRT efficiency, effectiveness, and identity. In Ottawa, for example, about half of the Transitway routes actually operate on the Transitway itself.

In most North American applications, the BRT service patterns that work best feature all-stop service at all times of day complemented by an "overlay" of integrated express services for specific markets during peak periods such as major park-and-ride stations to the CBD. This service pattern is found in Miami, Ottawa, and Pittsburgh. In Pittsburgh, more than half of the East Busway neighborhood's riders come from beyond the busway limits.

During off-peak periods, the integrated overlaid routes are turned back at BRT stations, converting the local portion of the routes into more cost-effective feeders. Where turnbacks are provided, good connecting schedules and communication facilities are essential, especially where feeders have long headways.

3.A.9 Traffic-Transit Integration

Close working arrangements between traffic engineers and transit planners are essential in developing busway and bus-lane designs, locations of bus stops and turning lanes, and application of traffic controls. A good program of traffic controls and signage will help ensure safe vehicle and pedestrian crossings of busways and bus lanes. Excessively long traffic signal cycle lengths to accommodate exclusive bus phases should be avoided.

Los Angeles's successful Metro Rapid bus operations on Wilshire-Whittier and Ventura Boulevards are a direct result of cooperation between the Metropolitan Transportation Authority and the city's DOT. The two agencies found that (1) a modest "advance" or "extension" of the traffic signal green time (or a delay of the red signal time) of up to 10 seconds per cycle can reduce bus delays with negligible impacts on cross street traffic, (2) bus headways should not be less than 2.5 to 3.0 minutes to enable major cross streets to "recover" from the time lost, and (3) far-side stops are essential.

An at-grade busway has fewer traffic impacts on intersecting roads than a typical arterial street. However, relatively light bus volumes require traffic control strategies that ensure safety at grade crossings. Positive protection, such as bus-actuated traffic signals, is essential. However, if accidents persist, gating of bus crossings may be appropriate. The busway should be treated as though it were a high-speed light rail line on a private right-of-way. If there is sufficient conflict among various modes (i.e., vehicles, transit vehicles, and pedestrians), it is important to incorporate gates to reduce these conflicts.

3.A.10 Performance

The case studies indicate that BRT can provide sufficient capacities for most corridors in most North American cities. The Ottawa and Pittsburgh busways carry peak-hour, peak-direction passenger flows of 8,000 to 10,000 people. These flows exceed the peak ridership on many U.S. and Canadian LRT lines. Curitiba's median busways routinely carry over 14,000 people per hour per direction, and Bogotá's system carries over 25,000 people per hour per direction. These flows exceed any expected rapid-transit passenger volumes that are likely in major corridors in the United States and in other developed countries.

Revenue speeds of 25 to 35 miles per hour are obtained on grade-separated busways in Pittsburgh and Ottawa for all-stop routes. Express routes have end-to-end revenue speeds of over 40 miles per hour. In Los Angeles, the arterial Metro Rapid routes achieve speeds up to 19 miles per hour. Two-thirds of the increase in travel speed in Los Angeles was due to fewer stops, and one-third was due to traffic signal priorities.

A main reason for the increased operating speeds on BRT systems is the wide spacing between stops. This suggests that BRT lines should have the widest station spacing that is feasible, which is generally a half-mile or more.

The Los Angeles experience showed that a combination of several BRT elements can achieve a 25% to 30% reduction in bus travel times and corresponding gains in ridership. These BRT elements include distinctive buses and stations, wide spacing between bus stops, and modest traffic signal priorities. The Los Angeles demonstration reported a 1% increase in riders for every 1% decrease in travel times. In fact, about one-third of the gain represented new transit riders, one-third was riders diverted from other routes, and one-third was existing riders making the trip more often.

A fixed-transit facility with frequent service can increase ridership. Regardless of travel time advantage, the presence or identity of the service can enhance ridership, as in Miami. The perceived permanence of the running way appears to have benefited ridership.

3.B CONCLUSIONS: SIGNIFICANCE AND EXTENSION

Examination of the case studies shows that BRT does work. BRT systems can attract new riders to transit and induce transit-oriented land use and economic development in a broad variety of environments. Virtually all new, fully integrated BRT system investments have experienced the same type of ridership increases previously thought to be the exclusive province of rail transit. For example, in Los Angeles, more than

30% of the additional trips generated by Metro Rapid bus service were made by riders who had not previously used transit.

At the same time, BRT can also have positive development effects. Ottawa, Pittsburgh, and Brisbane have demonstrated that there can be a positive connection between BRT investment and the location and site design of new land development.

The following is a summary of important points:

- BRT can provide sufficient capacities to meet peak-hour travel demands in most corridors in the United States and Canada.
- BRT should be rapid and reliable. Reliably high speeds can best be achieved when a large portion of the service can be provided on separate rights-of-way.
- BRT implementation and operating and maintenance costs are generally less than those of rail rapid transit. However, developing an effective BRT system is not always low cost.
- Any major BRT investment should be reinforced by transit supportive land-development and parking policies. BRT should be an integral part of land use, transportation, economic development, and master-planning efforts.
- In the future, it is expected that more cities will implement integrated BRT systems. There is tremendous payoff potential in keeping all elements of BRT together in an integrated package, although that may be difficult and challenging to implement. Although all communities may not have sufficient ridership markets or may have financial or physical limitations that prevent full system integration, many of the individual components can be adapted by existing bus systems to improve their attractiveness and utility.

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APPENDIX A

SUMMARY TABLES COMPARING BRT SYSTEMS

TABLE A-1 Summary of BRT systems surveyed

City	Urbanized Area Population (Millions)	Central Business District (CBD) Employment	Rail Transit in City	BRT Status/ Year First Opened	System Overview
US/CANADA					
1. Boston	3.0	365,000	√	First Section Opened July 2002	"Silver" Line includes bus tunnel and will have articulated dual-mode trolley and CNG-powered buses.
2. Charlotte	1.1	50,000		1997	Use of peak-period freeway bus lane by express buses in Independence Blvd. Corridor.
3. Cleveland	2.0	100,000	√	Under Construction	Euclid Ave. Median Busway will have articulated hybrid diesel-electric buses.
4. Eugene	0.2	N/A		Proposed	Project includes exclusive transit lanes used by low-floor guided vehicles.
5. Hartford	0.8	52,000		Under Construction	New Britain–Hartford Busway with stations along unused railroad busway.
6. Honolulu	0.9	N/A		1999	Three City Express! and Country Express! routes provide limited-stop service using distinctively colored articulated buses.
7. Houston	1.8	150,000		1979	Harbor and Santa Monica Freeway HOV lanes have express bus service and stations.
8. Los Angeles	9.6[(1)]	200,000	√	1977	San Bernadino Busway (later HOV Busway) opens.
				1979	Harbor and Santa Monica Freeway HOV lanes have express bus service, stations.
				1999	Wilshire-Whittier and Ventura Blvds. "Metro Rapid" limited-stop service uses distinctively colored low-floor CNG buses.
9. Miami	2.3	50,000	√	1996	Miami–South Dade Busway along abandoned railroad line connects with Miami Metro.
10. New York City	16.0	1,850,000	√	1963	Express buses use contra-flow bus lanes on three radial freeways; extensive bus lane network in Manhattan; limited-stop bus service on 25 routes in all 5 boroughs.
11. Ottawa	0.7[(2)]	86,500		1983	Extensive busway system with attractive stations offers all-stop and express service.
12. Pittsburgh	1.7	140,000	√	1977	South, East, and West Busways offer all-stop and express service.

(continued)

TABLE A-1 *(continued)*

CITY	URBANIZED AREA POPULATION (MILLIONS)	CENTRAL BUSINESS DISTRICT (CBD) EMPLOYMENT	RAIL TRANSIT IN CITY	BRT STATUS/ YEAR FIRST OPENED	SYSTEM OVERVIEW
13. Seattle	1.8	120,000		1990	Bus tunnel is used by articulated dual-mode trolley and diesel buses.
14. Vancouver	2.1	130,000	√	1996	Broadway and Richmond “B-Line” limited-stop BRT service using distinctive low-floor articulated buses.
AUSTRALIA					
15. Adelaide	1.1	N/A	√	1989	O-Bahn 7-mile guided busway offers both express and local service.
16. Brisbane	1.5	60,000	√	1990	South East Busway BRT with attractive stations offers both express and all-stop service. Buses use CBD bus tunnels.
17. Sydney	1.7	400,000	√	Under Construction	Liverpool-Parramatta BRT will include busways, bus-only roads, and stations. Service pattern will provide both express and all-stop routes.
EUROPE					
18. Leeds (U.K.)	0.7	N/A		1995	“Superbus” guided buses bypass queues in Scott Road Corridor and is under construction in York and Selby Road Corridor.
19. Rouen (France)	0.4	N/A	√	2001	Three-route optically guided buses use modern Irisbus Civis “train-like” buses.
20. Runcorn (U.K.)	0.1	N/A		1973	“Figure 8” busway system is integrated with development in planned New Town.
SOUTH AMERICA					
21. Belo Horizonte (Brazil)	2.2	N/A	√	1981	Avenida Christiano Machado Median busway, with passing capabilities at station.
22. Bogotá (Colombia)	5.0	N/A		2000	23-mile, 4-lane “TransMilenio” median busway with high-platform center island stations, where fares are paid, is served by articulated buses.
23. Curitiba (Brazil)	1.6	N/A		1973	5 median busway system along 5 structural axes is carefully integrated with city development. Bi-articulated buses provide frequent rapid-transit service to high-platform stations, terminals. Express (direct) service on nearby one-way streets.

(continued)

TABLE A-1 *(continued)*

CITY	URBANIZED AREA POPULATION (MILLIONS)	CENTRAL BUSINESS DISTRICT (CBD) EMPLOYMENT	RAIL TRANSIT IN CITY	BRT STATUS/ YEAR FIRST OPENED	SYSTEM OVERVIEW
24. Porto Alegre (Brazil)	1.3	N/A	√	1978	Four-corridor median busway system uses bus-ordering system to accommodate heavy passenger and bus flows.
25. Quito (Ecuador)	1.5	N/A		1996	Trolebus median busway system utilizes articulated, all-electric, trolley buses and high-platform stations with fare prepayment.
26. Sao Paulo (Brazil)	8.5	Over 1.0 million	√	1975	Extensive busway system includes D-Julho and Sao Mateua Sabaquara. Median busways have staggered island platform stations with passing capabilities.

Source: Individual Case Studies.
(1) Country Population. (2) Excludes Hull, Quebec.

TABLE A-2 BRT system features

City	Urbanized Area Population (Millions)	Facility Description	Running Way	Stations	Distinctive, Easy-to-Board Vehicles	Off-Vehicle Fare Collection	ITS	Frequent, All-day service
US/CANADA								
1. Boston	3.0	Silver Line – Bus Tunnel, Lanes	√	√	√	√	√	√
2. Charlotte	1.1	Independence Blvd. Freeway Busway	√	√				
3. Cleveland	2.0	Euclid Ave. – Arterial Median Busway	√	√	√		√	√
4. Eugene	0.2	Eugene-Springfield Arterial Median Transit Corridor Phase 1 (East-West)	√	√	√	√	√	√
5. Hartford	0.8	New Britain–Hartford Busway	√	√			√	
6. Honolulu	0.9	City Express! and County Express! (Mixed Traffic)	√	√	√			√
7. Houston	1.8	High Occupancy Vehicle (HOV) Lane System	√	√	e			
8. Los Angeles	9.6	Harbor Freeway HOV/Busway San Bernardino Freeway HOV/Busway Wilshire-Whittier & Ventura Metro Bus (Mixed Traffic)	√	√	√		√	√
9. Miami	2.3	Miami-S. Dade Busway	√	√				√
10. New York City	16.0	I-495 NJ, I-495 NY, Gowanus AM Contra-Flow Lanes Arterial Limited Stop Service	√	√				√
11. Ottawa	0.7	Transitway System (Busway, Bus Lanes)	√	√			√	√
12. Pittsburgh	1.7	South, East, West Busways	√	√				√
13. Seattle	1.8	Bus Tunnel	√	√	√			√
14. Vancouver	2.1	Broadway & Richmond "B" Lines (Mixed Traffic)	a	√	√		√	√
AUSTRALIA								
15. Adelaide	1.1	O-Bahn Guided Busway	√	√				√
16. Brisbane	1.5	South East Busway	√	√			√	√
17. Sydney	1.7	Liverpool-Parramatta Busway – Bus Lanes	√	d			√	d

(continued)

TABLE A-2 *(continued)*

City	Urbanized Area Population (Millions)	Facility Description	Running Way	Stations	Distinctive, Easy-to-Board Vehicles	Off-Vehicle Fare Collection	ITS	Frequent, All-day service
EUROPE								
18. Leeds (U.K.)	0.7	Superbus Guided Bus System	b	d				√
19. Rouen (France)	0.4	Optically Guided Bus – Bus Lanes	√	√	√	g	√	√
20. Runcorn (U.K.)	0.1	Figure 8 Busway	√	√				√
SOUTH AMERICA								
21. Belo Horizonte (Brazil)	2.2	Avenida Christiano Median Busway	√	c				√
22. Bogotá (Colombia)	5.0	TransMilenio Median Busway	√	√	√	√	√	√
23. Curitiba (Brazil)	1.6	Median Busway System	√	√	√	√	√	√
24. Porto Alegre (Brazil)	1.3	Assis Brasil & Farrapos Median Busways	√	d				
25. Quito (Ecuador)	1.5	Trolebus Median Busway	√	√	√	√	√	√
26. Sao Paulo (Brazil)	8.5	9 De Julho & Jaraquara Median Busways	√	f				√

Source: Individual Case Studies.
Notes:
(a) Has a short median busway.
(b) Queue bypasses at congested locations.
(c) 4 terminal stations.
(d) Not specified.
(e) Uses over-the-road coaches.
(f) Median bus stops.
(g) Limited.

TABLE A-3 Running way characteristics

City	Urbanized Area Population (Millions)	Facility Description	Length (Miles)	Number of Stations	Costs (millions)	Comments
US/CANADA						
1. Boston	3.0	Silver Line – Bus Tunnel, Lanes		10	$1.35 US	Full development (includes subway)
2. Charlotte	1.1	Independence Blvd. Freeway Busway	2.9	0		
3. Cleveland	2.0	Euclid Ave. – Arterial Median Busway	7.0	30	$220 US	
4. Eugene	0.2	Eugene-Springfield Phase I East-West Corridor	4.0	N/A	$11 US	Phase I
5. Hartford	0.8	New Britain–Hartford Busway	9.6	12	$100 US	
6. Honolulu	0.9	City Express! and County Express! (Mixed Traffic)	26.6			Excludes Country Express! mileage transit centers
7. Houston	1.8	High Occupancy Vehicle (HOV) Lane System	111.0		$980 US	
8. Los Angeles	9.6[a]	Harbor Freeway HOV/Busway	11.8	9	N/A	
		San Bernardino Freeway HOV/Busway	12.0	3	$75.0 US	
		Wilshire-Whittier (Mixed Traffic)	26.0	30	$5.0 US	
		Ventura Metro Bus (Mixed Traffic)	16.0	15	$3.3 US	
9. Miami	2.3	Miami-S. Dade Busway	8.2	15	$59.0 US	
10. New York City	16.0	I-495 NJ, I-495 NY, Gowanus	2.5	0	$0.7 US	
		AM Contra-Flow Lanes	2.2	0	$0.1 US	
		Arterial Limited Stop Service	5.0	0	$10.0 US	
11. Ottawa	0.7[b]	Transitway System (Busway, Bus Lanes)	37.0	28	$435 C	
12. Pittsburgh	1.7	South Busway	4.3	9	$27 US	
		East Busway	6.8	6	$113 US	
		West Busway	5.0	6	$275 US	
13. Seattle	1.8	Bus Tunnel	2.1	3	$450 US	
14. Vancouver	2.1	Broadway "B" Line (Mixed Traffic)	11.1	14	$13 C	Includes cost for Richmond Center Busway
		Richmond "B" Line (Mainly Traffic)	9.8	N/A	$46.9 C	
AUSTRALIA						
15. Adelaide	1.1	O-Bahn Guided Busway	7.4	3	$104 A	
16. Brisbane	1.5	South East Busway	10.5	10	$400 A	Stations on busway exclude downtown tunnel costs
17. Sydney	1.7	Liverpool-Parramatta Busway – Bus Lanes	19.0	35	$200 A	13 miles busway 6.0 miles bus lanes

(continued)

TABLE A-3 *(continued)*

CITY	URBANIZED AREA POPULATION (MILLIONS)	FACILITY DESCRIPTION	LENGTH (MILES)	NUMBER OF STATIONS	COSTS (MILLIONS)	COMMENTS
EUROPE						
18. Leeds (U.K.)	0.7	Superbus Guided Bus System	0.9	N/A	1.35 US	
19. Rouen (France)	0.4	Optically Guided Bus – Bus Lanes	28.5	61	200 US	Costs for 2 main lines based on 12.2 million per mile
20. Runcorn (U.K.)	0.1	Figure 8 Busway	14.0	56	15.0 US	¼-mile spacing
SOUTH AMERICA						
21. Belo Horizonte (Brazil)	2.2	Avenida Christiano Median Busway	5.6	15	N/A	200-ft stop spacing
22. Bogotá (Colombia)	5.0	TransMilenio Median Busway	23.6	59	184 US	Based on $8 million/mile
23. Curitiba (Brazil)	1.6	Median Busway System	37.2	139		410-ft stop spacing
24. Porto Alegre (Brazil)	1.3	Assis Brasil Median Busway Farrapos Median Busway	3.6 3.3	10 9		1960-ft stop spacing
25. Quito (Ecuador)	1.5	Trolebus Median Busway	10.0	32	57.6 US	1640-ft stop spacing
26. Sao Paulo (Brazil)	8.5	9 De Julho Median Busway Jaraquara Median Busway	7.0 13.0	18 34		2000-ft stop spacing

Source: Individual Case Studies

Notes:

N/A – Not Available
A – Australian dollars
C – Canadian dollars
US –US dollars

[a] Los Angeles County only
[b] Excludes Hull, Quebec which brings population to over 1 million

TABLE A-4 Station characteristics (selected systems)

City	Facility Description	Number of Stations	Average Station Spacing (Feet)	Location	Length in Feet (Number of Buses)	Passing Lanes	Platform Height	Fare Collection (Pre-Payment)
US/CANADA								
1. Boston	Silver Line – Bus Tunnel/ Lanes[1]	10	2,160	Side, Tunnel, Curb, Surface	220 (3)	Selected Tunnel Stations	Low	In Tunnel
3. Cleveland	Euclid Ave. – Arterial Median Busway	30	1,230	Median CBD Side Elsewhere	(2)	In CBD	Low	Possibly
4. Eugene	Phase I East-West Corridor	8	2,400	Median	160 (2)	Yes	Low	Yes
5. Hartford	New Britain–Hartford Busway	12	4,220	Side	(2)	Yes	Low	No
7. Houston	High Occupancy Vehicle (HOV) Lane System		N/A	Off-line	N/A	N/A	Low	No
8. Los Angeles	Harbor Freeway Busway	9	7,240	Side				
	San Bernardino Freeway HOV/Busway	3	21,000	Center				
	Wilshire-Whittier Metro Bus	30	4,580	Curb		General Traffic Lanes	Low	No
	Ventura Metro Bus	15	5,630	Curb			Low	No
9. Miami	Miami-S. Dade Busway	15	2,890	Side	(2–3)	Yes	Low	No
10. New York City	AM Contra-Flow Lanes	0		Side	N/A	Some	Low	No
11. Ottawa	Transitway System (Busway, Bus Lanes)	28	6,980	Side	180	Yes	Low	No
12. Pittsburgh	South, East, & West Busways	21	4,200	Side	120–240	Yes	Low	No
13. Seattle	Bus Tunnel	3	3,870	Side	(2)	Yes	Low	No
14. Vancouver	Broadway "B" Line (Mixed Traffic)	14	4,190	Side	N/A	Traffic Lanes	Low	No
	Richmond "B" Line (Mixed Traffic)	N/A	N/A	Side	N/A	Traffic Lanes		
AUSTRALIA								
15. Adelaide	O-Bahn Guided Busway[2]	3				None	Low	No
16. Brisbane	South East Busway	10	5,540	Side	N/A	Yes	Low	Ticket Machine
17. Sydney	Liverpool-Parramatta Busway – Bus Lanes	35	2,870	Curb	N/A	N/A	Low	No

(continued)

TABLE A-4 *(continued)*

City	Facility Description	Number of Stations	Average Station Spacing (Feet)	Location	Length in Feet (Buses)	Passing Lanes	Platform Height	Fare Collection (Pre-Payment)
EUROPE								
18. Leeds (U.K.)	Superbus Guided Bus System	3	N/A	Island	(1)	No	Low	No
19. Rouen (France)	Optically Guided Bus – Bus Lanes	61	2,470	Curb or Island	Limited	Yes	Low	Some
20. Runcorn (U.K.)	Figure 8 Busway	56	1,320	Curb	(2)	Yes	Low	No
SOUTH AMERICA								
21. Belo Horizonte (Brazil)	Avenida Christiano Median Busway	15	2,000	Side	(1–4)	Yes	Low	Some
22. Bogotá (Colombia)	TransMilenio Median Busway	59	2,110	Center Island	130–490	Yes	High	Yes
23. Curitiba (Brazil)	Median Busway System[3]	139	1,410	Side, Island	80 (1)	Yes	High	Yes
24. Porto Alegre (Brazil)	Assis Brasil Median Busway	10	1,000	Side	N/A	Yes	Low	No
	Farrapos Median Busway	9	1,000	Side	N/A	Yes	Low	No
25. Quito (Ecuador)	Trolebus Median Busway	32	1,640	Side, Center	(1)	No	High	Yes
26. Sao Paulo (Brazil)	9 De Julho Median Busway	18	2,000	Side	(2–3)	Yes	Low	Some
	Jaraquara Median Busway	34	2,000	Side	(2–3)	Yes	Low	Some

Source: Individual Case Studies

Notes:

N/A – Not Available
[1] Four stations in tunnel, six on surface
[2] Three stations on guided busway
[3] 139 stations including 26 integration terminals

TABLE A-5 Station features and amenities (selected systems)

CITY	FACILITY	FEATURES
1. Boston	Silver Line	Mezzanines in 4 tunnel stations with fare collection provisions. 6 curbside stations on Washington Street have seating, information panels, telephones, trash receptacles, and communications panel.
3. Cleveland	Euclid Ave.	Shelters, amenities, and possibly fare vending machines.
5. Hartford	New Britain–Hartford Busway	Passenger drop-off areas, some park-and-ride. Full range of amenities, climate-controlled buildings, restrooms, and telephones at major stations.
7. Houston	Transit Centers	Have extensive park-and-ride lots at stations.
8. Los Angeles	San Bernardino HOV/Busway Wilshire-Whittier Ventura Metro Bus	Circular island at El Monte Station, large park-and-ride lot there. Major stations – double canopy, "Next Bus" display signs. Other stations – single canopy shelter and bollards.
9. Miami	South Miami-Dade	Translucent, waterproof, fiber canopies; pay telephones; and benches.
10. New York City	I-495 Bus Lane	New Jersey buses use 200-berth Midtown Bus Terminal.
11. Ottawa	Transitway System	Passenger shelters, radiant heat, benches, telephones, television monitors announcing bus arrivals.
12. Pittsburgh	Busways	Simple shelters, some with telephones.
13. Seattle	Bus Tunnel	Architectural features such as murals/clocks.
14. Vancouver	B-Lines	Well-lit, distinctive shelters; real-time electronic bus information displays; customer information signage.
15. Adelaide	On Guided Busway	Protected shelters; bicycle access/storage; short-/long-term parking.
16. Brisbane	South East Busway	Architecturally distinctive designs, passenger protection, elevators and stairs, covered pedestrian bridges over busway, real-time passenger information, displays, ticketing machines, public telephones, passenger seats, drinking fountains, retail kiosks, public restrooms, security systems.
17. Sydney	Liverpool-Parramatta Busway – Bus Lanes	Real-time passenger information, lighting, and security cameras.
20. Rouen	Optically Guided Bus Lanes	Most stations are simple bus shelters; some have ticketing provisions.
22. Bogotá	TransMilenio	Similar to rapid-transit station in design; fare payment provisions; high platform.
23. Quito	Trolebus	Tube-like shelter at stations; off-vehicle fare collection; high platform.

TABLE A-6 Vehicle characteristics (selected systems)

CITY	FACILITY	VEHICLE TYPE	PROPULSION	LEVEL BOARDING	NO. OF DOORS	DOORS SIDE	DISTINCTIVE COLOR/LOGO
US/CANADA							
1. Boston	Silver Line	Articulated	Dual Mode-Trolley & CNG	√	3	Right	
2. Cleveland	Euclid Ave.	Articulated	Diesel-Electric Hybrid	√	3	Both	
4. Eugene	Phase I East-West Corridor	Articulated	Hybrid Electric	√	4	Both	Futuristic Vehicle
6. Honolulu	City Express! And Country Express!	Articulated		√	3	Right	Rainbow Wrap
7. Houston	HOV Express Buses	Over-the-Road Coaches, Articulated	Diesel		1	Right	
8. Los Angeles	Wilshire-Whittier-Ventura	Standard	CNG	√	2	Right	Red Colored Buses
9. Miami	South Dade Busway	Mini/Standard/Articulated	CNG, Diesel	Some	2	Right	
11. Ottawa	Transitway	Articulated/Standard	Diesel	Some	2–3	Right	
12. Pittsburgh	East-South-West Busways	Articulated/Standard	Diesel	Some	3	Right	
13. Seattle	Bus Tunnel	Articulated	Dual Mode Trolley/Diesel	√	3	Right	
14. Vancouver	Broadway/Richmond	Articulated	Diesel	√	3	Right	Distinctive Stripes
AUSTRALIA							
15. Adelaide	Guided Busway	Articulated	Diesel		2	Left	
16. Brisbane	South East Busway	Standard	CNG/Diesel	√	2	Left	
EUROPE							
18. Leeds	Superbus Guided Bus	Standard	Diesel	Some	1–2	Left	
19. Rouen	"Teor" System	Articulated	Civis-Irisbus Hybrid-Diesel Electric	√	4	Right	Distinctive Vehicle Appearance and Design
20. Runcorn	Figure 8 Busway	Regular	Diesel		2	Left	
SOUTH AMERICA							
21. Belo Horizonte	Avenida Christiano Machado	Standard	Diesel				
22. Bogotá	TransMilenio	Articulated	Diesel	√[a]	3	Left Double Width	Red Bus Special Bus
23. Curitiba	Busway System	Bi-articulated	Diesel	√[a]	5	Double Width Right	Distinctive Red Color
24. Porto Alegre	Assis Brasil Farrapas	Articulated	Diesel				
25. Quito	Trolebus	Articulated Trolley with Auxiliary	Diesel engines	√[a]	3	Right	Distinctive Rainbow Wrap
26. Sao Paulo	9 de Julio Jaraquara	Double-Deck, Standard, Articulated Varied	Trolley Diesel Trolley/Diesel		2–3 2–3	Both Both	

Source: Individual Case Studies.

[a] High-platform loading.

TABLE A-7 Application of ITS technologies (selected systems)

City	System	Automatic Vehicle Location (AVL)	Telephone Info/ Stations	Passenger Information Automated Station Announcements On Vehicle	Real-Time Info. At Stations	Traffic Signal Priorities
US/CANADA						
1. Boston	Silver Line	√	√	√	√	
2. Charlotte	Independence Corridor	√				√
3. Cleveland	Euclid Ave.					
4. Eugene	Arterial Median Transitway			√		√
5. Hartford	New Britain–Hartford Busway	√	√	√		
8. Los Angeles	Wilshire-Whittier & Ventura BRT	√				√
9. Miami	Miami-S. Dade Busway		√			Removed
11. Ottawa	Transitway		√	√	√ Selected Locations	
12. Pittsburgh	South-East-West Busways		√	Some Buses		
14. Vancouver	Broadway and Richmond "B" Lines	√		√	√	√
AUSTRALIA						
16. Brisbane	South East Busway	√		√	√	
17. Sydney	Liverpool-Parramatta BRT	√			√	
EUROPE						
19. Rouen	Optically Guided Bus			√		√ With Special Bus Signals
SOUTH AMERICA						
22. Bogotá[1]	TransMilenio	√				
23. Curitiba	Median Busway System			√		

Source: Individual Case Studies.
Note: [1] GPS and Control Center.

TABLE A-8 Service patterns

City	System	Operates on Facility Only	Express	All Stops	Limited Stops	Local Bus Service (same street)	Feeder Service
US/CANADA							
1. Boston	Silver Line Bus Tunnel & Lanes			√			√
2. Charlotte	Independence Blvd. Freeway Busway		√				
3. Cleveland	Euclid Ave. – Median Arterial Busway	√ [2]	√ [1]				√
4. Eugene	Arterial Median Transitway	√		√			√
5. Hartford	New Britain–Hartford Busway		√	√			√
6. Honolulu	City Express! and Country Express! Mixed Traffic				√		√
7. Houston	High Occupancy Vehicle (HOV) Lane System		√				
8. Los Angeles	Harbor Freeway Bus & HOV Way		√		√		
	San Bernardino Bus & HOV Way		√				
	Metro Bus – Wilshire-Whittier & Ventura Blvds.				√	√	
9. Miami	S. Miami-Dade Busway		√	√			√
10. New York City	Contra-Flow AM Bus Lanes		√				
	Arterial Limited-Stop Routes				√	√	√
11. Ottawa	Transitway		√	√			√
12. Pittsburgh	South-East-West Busways		√	√			√
13. Seattle	Bus Tunnel			√			√
14. Vancouver	Broadway "B" Line (Mixed Traffic)				√	√	√
	Richmond "B" Line (Mixed Traffic)				√	√	√
AUSTRALIA							
15. Adelaide	O-Bahn Guided Busway		√	√			
16. Brisbane	South East Busway		√	√			√
17. Sydney	Liverpool-Parmatta Busway Bus Lanes		√	√			√
EUROPE							
18. Leeds	Guided Bus System			√			
19. Rouen	Optically Guided System Bus Lanes				√		√
20. Runcorn	Figure 8 Busway			√			
SOUTH AMERICA							
21. Belo Horizonte	Avenida Christiano-Median Busway		√	√			
22. Bogotá	TransMilenio Median Busway	√		√	√		√
22. Curitiba	Median Busway System	√	√ [1]	√			√
23. Porto Alegre	Assis Brasil Median Busway		√	√			
	Farrapos Median Busway		√	√			
24. Quito	Trolebus Median Busway	√		√	√		
25. Sao Paulo	9 de Julio Median Busway		√	√			
	Jabaquara Median Busway		√	√			

Source: Individual Case Studies.

[1] Operates on nearby one-way streets.

[2] Under anticipated operating plan.

TABLE A-9 Passenger volumes, bus flows, and speeds (selected systems)

City	Facility (System)	Weekday Bus Riders	AM Peak-Hour, Peak-Direction		Speeds (MPH)	
			Buses	Riders	Express	All Stop
US/CANADA						
1. Boston	Silver Line Bus Tunnel/Lanes	40,000[(1)] 78,000[(e)]	75[(e)]	4,500		
2. Charlotte	Independence Blvd. Busway	1,000[(2)]				
3. Cleveland	Euclid Ave. Median Busway	29,500[(e)]				12
5. Hartford	New Britain–Hartford Busway	20,000[(3)]	20–24	1,000±	38	32
6. Honolulu	Route A City Express!	11,000[(4)]				
	Route B City Express!					
	Route C Country Express!					
7. Houston	HOV System KATY	9,115	48	2,100	54[(11)]	
	1-45 North	13,980	63	3,300	54	
	Northwest	6,180	34	1,500	54	
	Gulf	6,685	21	1,200	54	
	Southwest	8,900	54		54	
	Eastex	4,500	22	1,150	54	
8. Los Angeles	Harbor Bus HOV Way	9,600	40[(e)]	1,800[(e)]		35
	San Bernardino Bus HOV Way	18,000	70	2,750		43
	Wilshire-Whittier Metro Bus	40,000[(5)]	30	1,500	14	
	Ventura Blvd. Metro Bus	9,000[(6)]	15[(e)]	750[(e)]	19	
9. Miami	Miami-S. Dade Busway	12,000	20[(e)]	800 [(e)]	18	12–14
10. New York City	I-495 (NJ) Contra-Flow Lane		650–830[(7)]	25,000–35,000[(7)]	35	
	I-495 LI Exp. Contra-Flow Lane		125	5,240		
	I-278 Gowanus Contra-Flow Lane		175	6,180		
	Limited Stop Service – Arterials				8–14	
11. Ottawa	Transitway System	200,000	180–200	10,000	50	24
12. Pittsburgh	South Busway	13,000	50	2,000	40	30
	East Busway	28,000	110	5,400	40	30
	West Busway	7,000	40	1,700	40	30
13. Seattle	Bus Tunnel	46,000	70	4,200[(e)]		13
14. Vancouver	Broadway "B" Line	26,000	15	1,000[(e)]		14
	Richmond "B" Line	14,000	15	1,000[(e)]		14

(continued)

TABLE A-9 *(continued)*

City	Facility (System)	Weekday Bus Riders	AM Peak-Hour, Peak-Direction		Speeds (MPH)	
			Buses	Riders	Express	All Stop
AUSTRALIA						
15. Adelaide	O-Bahn Guided Busway	30,000		4,000		
16. Brisbane	South East Busway	60,000	150	9,500		
17. Sydney	Liverpool-Paramatta Busway/Lanes	18,000(e)				
SOUTH AMERICA						
21. Belo Horizonte	Avenida Christiano Machado Median Busway	1,500,000 Systemwide		16,000		17
22. Bogotá	TransMilenio Arterial Median Busway	800,000(8, 8a)		27,000(8, 8b)	19	13
23. Curitiba	Median Busway System	340,000	40	11,000	19	12
24. Porto Alegre	Assis Brasil Median Busway	290,000	326	26,100		11–14
	Farrapos Median Busway	235,000	304(9)	17,500		12–14
25. Quito	Trolebus	150–170,000	40	8,000		11–12
26. Sao Paulo	9 de Julio Median Busway	196,000	220+	18–20,000		12
	Jabaquaro Median Busway	230,000(10)		21,600		14

Source: Individual Case Studies.

Notes:

(1) Values in parentheses for Phase I
(2) Based on 15,700 monthly riders
(3) Year 2000 ridership
(4) Based on 300,000 riders per month
(5) BRT Service only – total daily riders on Wilshire approximate 100,000
(6) BRT Service only – total daily riders approximate 14,000
(7) Facility operates only during AM Peak period
(8) 45,000 total peak riders on system
(8a) Daily traffic with planned extension; about 600,000 existing riders.
(8b) Peak hour, peak direction
(9) PM Peak hour
(10) Based on 70 million riders per year
(11) Overall speeds including downtown distribution – about 25–30mph
(e) Estimated

TABLE A-10 Reported travel time savings compared with pre-BRT

City	Facility	Travel Time (Min)			Travel Time Savings		Comments
		Before	After	% Reduction	Total (Min)	Min/Mile	
US/CANADA							
Charlotte	Independence Blvd. Freeway Busway				5–15	1.7–5.1	
Cleveland	Euclid Ave. – Median Arterial Busway	41	32.75	20	8.25	1.2	Anticipated
Eugene	Arterial Median Busway	27	15	46	12	3	Peak Direction
Hartford	New Britain–Hartford Busway	34.6	20.1	42	14.5	1.5	Anticipated
Honolulu	City Express!	35	20	43	15	2.3	Phase I
Houston	HOV System – Addicks Park/Ride	45	24	47	21	1.1	
	Northwest Park/Ride	50	30	40	20	2.5	
Los Angeles	San Bernardino HOV Busway	48	17	38	31	2.6	3-Person HOV
	Wilshire-Whittier Blvd. Metro Bus	76	55	28	21	1.5	14 Miles
	Ventura Blvd. Metro Bus	56	43	23	13	0.9	14 Miles
New York City	I-495 Contra-Flow Lane (NJ)				18	7.2	AM Inbound
	I-495 L/E Contra-Flow Lane (NY)				15	7.5	Only
	I-278 Gowanus Contra-Flow Lane				20	4.0	Queue Bypass
	Arterial Limited-Stop Service (25 Routes)					0.9	Range by Borough 0.5–1.9
Pittsburgh	South Busway				6–11	1.4–2.6	
	East Busway (Busway Service)	51–54	30	41–44	21–24	3.1–3.5	EBA Route
	West Busway				25–26	5–5.2	AM Inbound Only
Seattle	Bus Tunnel	15	10	33	5	2.4	
Vancouver	Broadway "B" Line				3–10	0.4–0.9	
	Richmond “B” Line				10	1.0	
AUSTRALIA							
Adelaide	O-Bahn Guided Bus	40	25	38	15	2	
Brisbane	Southeast Busway					2	Estimated
Sydney	Liverpool-Parmatta Bus				60	3.1	Maximum Expected
EUROPE							
Leeds	Superbus - Guided Bus (AM peak)				3	10.7	450M Guideway
	Superbus - Guided Bus (PM peak)				5	10.0	800M Guideway
	Superbus - Guided Bus (AM peak)				10		Total System
SOUTH AMERICA							
Bogotá	TransMillenio			32			
Porto Alegre	Farrapos Arterial						
	Median Busway	24	17	29	7	2.1	

Source: Individual case studies

TABLE A-11 Reported increases in bus riders (selected systems)

CITY	FACILITY	DESCRIPTION
US / CANADA		
Charlotte	Independence Blvd. Freeway Busway	Monthly ridership increased from 10,100 to 15,700, a 55% increase, since January 1999.
Cleveland	Euclid Ave. Median Arterial Busway	Estimated increase due to BRT from 26,100 to 29,500 per day, or 13%.
Hartford	New Britain–Hartford Busway	Half of estimated 20,000 daily riders expected to be former motorists.
Honolulu	City Express! and Country Express!	Monthly ridership grew from 100,000 to 300,000 from 1999 to 2001.
Houston	Expressway HOV/Busway	18% to 30% of riders did not make the trip before. Up to 72% of riders were diverted from automobiles.
Los Angeles	Wilshire-Whittier and Ventura Metro Bus	26% to 33% gain in ridership. 1/3 of these were riders who made the trip more often, 1/3 were new riders, and 1/3 were diverted from other corridors.
Miami	Miami-South Dade Busway	50% initial ridership gain after service expansion.
Ottawa	Transitway System	Transitway ridership grew 6% from 1998 to 1999. System helps achieve a peak-hour CBD mode split of 70%.
Pittsburgh	East Busway	Riders on East Busway grew from 21,000 in 1983 to 29,000 in recent years (38% increase). In 1983, 1,900 new riders were attracted to the busway; 11% of riders on new routes and 7% on diverted routes had previously used automobiles.
Vancouver	Broadway-Lougheed "B" Line	8,000 new riders when service started. 20% previously used automobiles, 5% represented new trips, and 75% were diverted from another bus line.
AUSTRALIA		
Adelaide	Guided Busway System	Ridership grew from 4.2 million in 1986 to 7.4 million in 1996 (76% increase) at a time when regional transit ridership declined by 28%.
Brisbane	South East Busway	42% gain in ridership from May-October 2001. 375,000 fewer annual private vehicle trips.
EUROPE		
Leeds	Superbus Guided-Bus System	Over 50% reported ridership growth in first 2.5 years.
SOUTH AMERICA		
Curitiba	Median Busway System	Ridership has grown with system expansion and city growth, from 400,000 daily transit trips in 1982 to 1,900,000 in 2001. 27 million fewer automobile trips annually.

TABLE A-12 Development costs of selected BRT systems

CITY / FACILITY	Miles	Cost ($Million)	Cost/ Mile ($Million)	Notes
BUS TUNNELS				
Boston – Silver Line	4.1	1,350	329	Includes bus lanes
Seattle	2.1	450	214	
BUSWAYS				
Hartford	9.6	100	10	
Houston – HOV System	98	980	20	
Los Angeles – San Bernardino Freeway	12	75	6	
Miami	8.2	59	7	
Ottawa	37	293	8	
Pittsburgh – South Busway	4.3	27	6	
East Busway	6.8	130	19	
West Busway	5	275	55	
Adelaide (Guided Bus)	7.4	53	7	
Brisbane	10.5	200	19	Excludes cost of downtown bus tunnel built before busway
Liverpool-Parramatta	19	100	5	
Runcorn	14	15	1	
FREEWAY REVERSIBLE LANES				
New York – I-495 New Jersey	2.5	0.7	0.3	
I-495 New York	2.2	0.1	0.1	
I-278 Gowanus	5	10	2	Involves freeway reconstruction
ARTERIAL STREET MEDIAN BUSWAYS				
Cleveland	7	220	29	
Eugene	4	13	3.2	
Bogotá	23.6	184	8	
Quito	10	57.6	6	
Belo Horizonte			1.6	Excludes buses and terminals
MIXED TRAFFIC/CURB BUS LANES				
Los Angeles	42	8.3	0.2	
Vancouver – Broadway	11	9	1	
Richmond	9.8	44	4.1	
Leeds (Guided Bus)	2.1	5	2.4	
Rouen (Optically Guided Bus)	28.6	200	7	

Note: All costs are listed in U.S. dollars.

APPENDIX B

CASE STUDIES

Appendix B includes 26 case studies of BRT systems in North America, Australia, Europe, and South America and is available on *CRP-CD-31,* which accompanies this volume of *TCRP Report 90: Bus Rapid Transit.*

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation