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.