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.