ISSUES IN
BUS RAPID TRANSIT

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1.0 INTRODUCTION: CREATING BETTER BUS SYSTEMS

Bus systems provide a versatile form of public transportation with the flexibility to serve a variety of access needs and an unlimited range of locations throughout a metropolitan area. Because buses travel on urban roadways, infrastructure investments needed to support bus service can be substantially lower than the capital costs required for rail systems. As a result, bus service can be implemented cost-effectively on routes where ridership may not be sufficient or where the capital investment may not be available to implement rail systems.

Traffic congestion, urban sprawl, central city decline, and air pollution are all problems associated with excessive dependence on automobiles. Increasing recognition of the need for high-quality transit service to alleviate these conditions has fueled growing demand for new rail services throughout the United States (U.S.). Rail systems have in fact played an essential role in preserving and revitalizing the downtown areas of major American cities, ranging from New York to San Francisco and Washington, D.C. In these and numerous other cities, however, buses also provide an attractive and effective alternative to automobiles, reaching into central cities, local neighborhoods, and the suburbs to meet the mobility needs of millions of people.

Despite the inherent advantages of bus service in terms of flexibility and low capital cost, the traveling public frequently finds the quality of bus service provided in urban centers to be wanting. Conventional urban bus operations often are characterized by sluggish vehicles inching their way through congested streets, delayed not only by other vehicles and traffic signals, but also by frequent and time-consuming stops to pick up and discharge passengers. Buses travel on average at only around 60 percent of the speeds of automobiles and other private vehicles using the same streets due to the cumulative effects of traffic congestion, traffic signals, and passenger boarding. Moreover, compared to rail systems, the advantageous flexibility and decentralization of bus operations also result in a lack of system visibility and permanence that contributes to public perceptions of unreliability and disorganization.

1.1 What is Bus Rapid Transit?

Low-cost investments in infrastructure, equipment, operational improvements, and technology can provide the foundation for *Bus Rapid Transit* systems that substantially upgrade bus system performance. Conceived as an integrated, well-defined system, Bus Rapid Transit would provide for significantly faster operating speeds, greater service reliability, and increased convenience, matching the quality of rail transit when implemented in appropriate settings. Improved bus service would give priority treatment to buses on urban roadways and would be expected to include some or all of the following features:

- ***Bus lanes***: A lane on an urban arterial or city street is reserved for the exclusive or near-exclusive use of buses.

- ***Bus streets and busways***: A bus street or transit mall can be created in an urban center by dedicating all lanes of a city street to the exclusive use of buses.

- ***Bus signal preference and preemption***: Preferential treatment of buses at intersections can involve the extension of green time or actuation of the green light at signalized intersections upon detection of an approaching bus. Intersection priority can be particularly helpful when implemented in conjunction with bus lanes or streets, because general-purpose traffic does not intervene between buses and traffic signals.

- ***Traffic management improvements***: Low-cost infrastructure elements that can increase the speed and reliability of bus service include bus turnouts, bus boarding islands, and curb realignments.

- ***Faster boarding***: Conventional on board collection of fares slows the boarding process, particularly when a variety of fares is collected for different destinations and/or classes of passengers. An alternative would be the collection of fares upon entering an enclosed bus station or shelter area prior to bus arrivals. This system would allow passengers to board through all doors of a stopped bus. A self-service or "proof-of-payment" system also would allow for boarding through all doors, but poses significant enforcement challenges. Prepaid "smart" cards providing for automated fare collection would speed fare transactions, but would require that boarding remain restricted to the front door of the bus.

  Changes in bus or platform design that could provide for level boarding through the use of low-floor buses, raised platforms, or some combination thereof could make boarding both faster and easier for all passengers.

- ***Integration of transit development with land use policy***: Bus Rapid Transit and compact, pedestrian-oriented land use development are mutually supportive. The clustering of development has the additional benefit of conserving land and promoting the vitality of neighborhoods and urban commercial centers. Bus Rapid Transit can be most effective when integrated within a broader planning framework encompassing land use policies, zoning regulations, and economic and community development.

- ***Improved facilities and amenities:*** The operational and travel time benefits resulting from the separation of buses from general-purpose traffic can be augmented with improved amenities such as bus shelters and stations. These facilities provide protection from the elements and can also be equipped to furnish information such as printed routes and schedules or electronically transmitted real time schedule data. Space can also be leased to commercial convenience services.

1.2 Reducing Delay: The Key to Bus Rapid Transit

Bus operations on a typical urban or suburban arterial are subject to several types of delay that reduce bus operating speed to generally only 60 percent of that of other vehicles. Figure 1 is from Transit Cooperative Research Program Report 26, *Operational Analysis of Bus Lanes on Arterials.* This figure summarizes and graphically displays the several components of bus travel time such as moving, passenger stops, and traffic delay, which consists of traffic signal delay, right turn delay and general congestion delay. Figure 1 also shows how certain types of delay such as congestion delay and passenger stop delay are proportionately greater in more congested areas.

The essence of Bus Rapid Transit is that bus operating speed and reliability on arterial streets can be improved by reducing or eliminating the various types of delay. A discussion of each travel time component and methods for reducing delay follows:

1. Uncongested moving or free flow operating time

This component can only be reduced if speed limits are raised.

2. Delay due to general congestion

This component can be reduced if general congestion is reduced and/or if buses are given preferential treatment through creation of a reserved lane. Policies requiring general-purpose traffic to yield to buses re-entering the traffic stream from bus stops could also reduce delays associated with general congestion.

3. Delay due to traffic signals

Priority treatment of buses at intersections holds the potential to reduce a significant source of delay in bus operations. Today's traffic signal control systems are tightly interconnected, however, in order to provide progression of general traffic through urban grid networks. Therefore, bus signal priority treatments would have to be constrained to modest variations within the context of maintenance of progression. Bus operating speeds may also improve if traffic signal cycles are coordinated to the time required for passenger service, i.e., the red phase occurs during the time needed for passenger boarding and fare collection.

4. Delay due to right turns

This type of delay occurs when buses are traveling in the curb lane and a queue of right-turning vehicles blocks the bus from moving forward. This delay may be overcome by relocating bus stops to the far side of the intersection so the bus may be able to bypass the right turning queue in the lane next to the curb lane. Alternately, right turns may be prohibited as they were on Madison Avenue (with two exclusive bus lanes between 45th and 59th Streets) in New York City, significantly reducing bus travel times. This solution, however, may not be viable everywhere.

4. Delay due to passenger stops

This includes passenger boarding time, collection of fares, etc. Boarding time can be reduced by improvement of the fare collection process, e.g. pre-payment of fares, self-service fare collection (honor system), greater use of passes, smart cards, etc. and by easing the boarding process with low-floor buses together with high platforms so that wheelchair-bound passengers could roll on without lifts. This component can also be reduced if stop spacing is increased and the number of stops are reduced. There is a trade-off between stop spacing and convenience to passengers.

2.0 UNITED STATES EXPERIENCE

2.1 Busways and High-occupancy Vehicle Lanes

The history of bus infrastructure in the U.S. is intertwined with the development of high-occupancy vehicle (HOV) lanes. The 1970s inaugurated an era of vigorous development of busways and other HOV facilities. Exclusive busways or bus lanes were implemented on the Shirley Highway in the Washington, D.C. area, the El Monte Freeway in Los Angeles, the I-495 approach to the Lincoln Tunnel in New Jersey, California Highway 101 in the San Francisco metropolitan area, and a separate right-of-way in Pittsburgh. At the same time, HOV lanes open not only to buses, but also to vanpools and carpools, were being created on highways serving New York, Los Angeles, Seattle, San Francisco, Washington, D.C., and Honolulu.

With the exception of the I-495 lane in New Jersey and the Pittsburgh busway, the early highway exclusive bus lanes have all since been converted to HOV lanes, with carpools being the predominant users. During the 1980s, the number of freeway HOV route miles increased by over 100 percent, although there are several examples of highways -- such as the Santa Monica Freeway in Los Angeles and the Garden State Parkway in New Jersey -- where HOV lanes were discontinued due to insufficient usage or other problems, such as public opposition, which led to a court decision terminating the Santa Monica Freeway HOV treatment. There are now over 80 HOV facilities greater than 3.5 miles in length throughout the U.S.

At the same time that HOV and exclusive bus facilities were being implemented on the nation's highways, bus lanes and transit malls were introduced in the downtown areas of many cities. The most prominent examples include the Nicollet Mall in Minneapolis, the Portland Transit Mall in Portland, Oregon, and the 16th Street Mall in Denver, all of which are still in operation. Bus lanes were introduced on New York City's Madison Avenue on May 26, 1981, reducing bus travel times by 34 to 42 percent and increasing ridership by 10 percent. Some downtown and arterial bus lane projects implemented in the 1970s and 1980s have been discontinued or cut back, however, and there are only a few cases in which infrastructure investments have been integrated into a high quality bus transit network.

The premier examples of high quality bus transit facilities in the U.S. are in Pittsburgh, Seattle, and Miami. The Port Authority of Allegheny County operates two 2-lane busways in the Pittsburgh metropolitan area: the 7-mile East Busway, which shares right-of-way with light rail transit, and the 4-mile South Busway. A 5-mile Airport Busway currently is under construction. These facilities serve express buses traveling to the downtown area, where several bus lanes operating on city streets expedite local access and distribution. The opening of the East Busway in 1983 reduced travel times by 15 to 23 percent on the various bus routes served. In Seattle, a regional network of freeway HOV lanes connects buses to a core of underground tunnels in the city center, where grade separation allows buses to operate in a rapid transit mode, bypassing traffic congestion on surface streets. The 8.2-mile South Dade Busway opened on February 3, 1997, connecting to the southernmost stops on Miami's Metrorail. The 2-lane busway, which parallels U.S. Route 1, is served by 16 stations. Eleven bus routes serving Dade County now operate on or feed the busway.

2.2 Problems of Arterial Bus Priority Treatments

Extensive development of HOV lanes throughout the U.S. represents a significant effort -- illustrated most clearly in the case of busways -- to improve bus service on the highways connecting suburban and downtown areas. Providing high quality service within the downtown sections of metropolitan areas is key to the Bus Rapid Transit concept, however, and has not been the subject of a comparable effort. While busways and freeway HOV facilities can substantially reduce travel times and improve service, mobility within congested urban centers is essential to support the economic and social functions of cities and to sustain high levels of transit ridership.

In most cities, a number of factors impede the upgrading of right-of-way to provide for exclusive bus lanes on arterial and local city streets. The most basic obstacle to creating a bus lane on a city street is the lack of an adequate cross section to separate buses from general-purpose traffic. At a minimum, bus lanes require an 11-foot cross section per direction. On most major two-way streets, the creation of even a single direction, reversible bus lane will limit at least one direction of general-purpose traffic to a single lane, likely producing serious adverse consequences for general-purpose traffic. There may be more opportunities to dedicate a lane for exclusive bus use on relatively wide one-way streets, although in many cases this too will produce adverse effects on general-purpose traffic flows and losses of scarce on-street parking spaces.

Depending on whether a bus lane is located along the curb or in the median of a two-way street, conflicts are created with right- or left-turning vehicles. The need to allow general-purpose traffic to use a bus lane for turning interferes with bus operations, causing substantial increases in travel time and adding to the problems of enforcing the restriction of the lane to buses under all other circumstances. Curbside parking by delivery and service vehicles also obstructs bus movement and is particularly problematic if the bus lane is restricted to only a single lane width. Dual-width bus lanes are markedly superior to single-width lanes, but obviously require a substantially wider cross section, which typically is not available. In the case of a median lane, another drawback is that passengers must walk across general-purpose traffic lanes to reach the bus stop.

As a practical matter, traffic signal priority or preemption can be implemented effectively only in conjunction with dedicated bus lanes, streets, or where geometry allows, queue bypass lane segments that allow buses to circumvent traffic at an intersection approach. A major limitation on bus signal preference is the adverse effect associated with the reduction of green signal time for general-purpose traffic on the cross streets. Moreover, the constraints imposed by traffic signal progression will limit the effective application of signal preemption in many urban arterial street networks.

From the standpoint of bus service quality, there is a trade-off between the improvement in travel times that can be achieved by reducing the number of stops, as in the case of rapid rail service, versus the convenient access made possible by frequent stops, as in conventional bus service. A number of inherent difficulties also affect efforts to reduce boarding times. An innovation that promises to speed the time required for payment of fares is the use of "smart" card electronic systems. Nevertheless, this improvement will not eliminate the need to restrict boarding to the front door of the bus.

One potential option for alleviating this and other physical constraints on boarding would be greater use of enclosed bus waiting areas or stations where passengers would be required to enter the waiting areas in advance, thus allowing boarding through all doors of the bus. Enclosed boarding areas take up significant sidewalk space, however, which may not be available in many locations. Moreover, capital, operating, and maintenance costs are likely to limit the number of such facilities that can be provided, even in areas where spatial constraints are not a significant problem. Thus, if the convenience of frequent stops is to be maintained, conventional boarding procedures would continue at many or most locations.

System integration is an issue arising from the need to provide for transfers between routes where passengers pay fares upon entering boarding areas and routes with on board payment. Another potential concern is that specialized vehicle boarding features designed to be compatible with platforms in enclosed areas may impose constraints on the deployment of a transit system's vehicle fleet.

2.3 Examples of Recent or Planned Implementation of Bus Rapid Transit Elements

Several U.S. and Canadian cities have introduced or are in the process of implementing elements of Bus Rapid Transit, as illustrated in the following examples.

- ***Eugene, Oregon* -** After determining that Bus Rapid Transit would cost about 4 percent of a comparable light rail system, Eugene officials decided to implement Bus Rapid Transit in a pilot corridor by 1999. This service will consist of a main truck route and feeder routes to provide neighborhood connections. Some of the features to be incorporated include easy boarding, low-floor buses on the main corridor, smaller neighborhood feeder buses, signal priority for buses at intersections, dedicated bus lanes, prepaid fares from bus ticket vending machines and passes to speed boarding, and comfortable transit stations. Planners hope the new system will be competitive with the automobile and provide frequent bus service with little or no waiting on the main travel corridors.

- ***Orlando, Florida* -** Orlando's Lymmo system offers passengers free bus rides throughout the downtown area on three miles of dedicated lanes. Ten low-floor buses fueled by environmentally-friendly compressed natural gas run every 5 minutes during working hours, every 10 minutes after hours, and every 15 minutes on weekends between eleven lighted and computerized Lymmo stations and eight additional stops. Service is fast because low-floor buses speed passenger loading, even for passengers with wheelchairs, and because signal priority for buses at intersections insures that traffic does not interfere with bus operations. Electronic kiosks at stations show passengers the location and expected arrival time of the next bus.

- ***Cleveland, Ohio* -** Plans are under way in Cleveland for exclusive bus lanes on 5.6 miles of Euclid Avenue, connecting the downtown area with University Circle, another of the city's major employment centers. This major infrastructure investment will be implemented in conjunction with the development of a "Transit Zone" throughout the downtown area that will feature expanded and more visible bus operations and more convenient transfers between crosstown bus routes.

- ***Ottawa, Ontario* -** Ottawa's Transitway, built in stages from 1978 through 1996, is a 19-mile bus-only road leading to the central business district, where it connects to exclusive bus lanes on city streets. Over 75 percent of passenger bus trips are made using the Transitway. The Transitway was constructed largely on rail rights-of-way and was designed for possible conversion to rail should ridership warrant. The main Transitway routes use articulated buses with proof-of-payment fare collection to speed boarding -- only one quarter of the riders pay cash. Feeder buses operate on a timed transfer system.

3.0 CURITIBA EXPERIENCE

The bus system of Curitiba, Brazil, exemplifies a model Bus Rapid Transit system, and plays a large part in making this a livable city. The buses run frequently -- some as often as every 90 seconds -- and reliably, commuters ride them in great numbers, and the stations are convenient, well-designed, comfortable, and attractive. Curitiba has one of the most heavily used, yet low-cost, transit systems in the world. It offers many of the features of a subway system -- vehicle movements unimpeded by traffic signals and congestion, fare collection prior to boarding, quick passenger loading and unloading -- but it is above ground and visible. Even with one automobile for every three people, one of the highest automobile ownership rates in Brazil, and with a significantly higher per capita income than the national average, around 70 percent of Curitiba's commuters use transit daily to travel to work. Greater Curitiba with its 2.2 million inhabitants enjoys congestion-free streets and pollution-free air.

3.1 Evolution of the Bus System

The bus system did not develop overnight, nor was it the result of transit development isolated from other aspects of city planning. It exists because thirty years ago Curitiba's forward-thinking and cost-conscious planners developed a Master Plan integrating public transportation with all elements of the urban system. They initiated a transportation system that focused on meeting the transportation needs of the population -- rather than focusing on those using private automobiles -- and then consistently followed through over the years with staged implementation of their plan. They avoided large scale and expensive projects in favor of hundreds of modest initiatives.

A previous comprehensive plan for Curitiba, developed in 1943, had envisioned exponential growth of automobile traffic and wide boulevards radiating from the central core of the city to accommodate the traffic. Rights of way for the boulevards were acquired, but many other parts of the plan never materialized. With the adoption of the new Master Plan in 1965, the projected layout of the city changed dramatically. The Master Plan sprang from a competition among urban planners prompted by fears of city officials that Curitiba's rapid growth, if unchannelled, would lead to the congested, pedestrian-unfriendly streets and unchecked development that characterized their neighbor city, São Paulo, and many other Brazilian cities to the north.

As a result of the Master Plan, Curitiba would no longer grow in all directions from the core, but would grow along designated corridors in a linear form, spurred by zoning and land use policies promoting high density industrial and residential development along the corridors. Downtown Curitiba would no longer be the primary destination of travel, but a hub and terminus. Mass transit would replace the car as the primary means of transport within the city, and the high density development along the corridors would produce a high volume of transit ridership. The wide boulevards established in the earlier plan would provide the cross section required for exclusive bus lanes in which express bus service would operate.

3.2 The Bus System

Curitiba's bus system evolved in stages over the years as phases of the Master Plan were implemented to arrive at its current form. It is composed of a hierarchical system of services. Small minibuses routed through residential neighborhoods feed passengers to conventional buses on circumferential routes around the central city and on interdistrict routes. The backbone of the bus system is composed of the express buses operating on five main arteries leading into the center of the city much as spokes on a wheel lead to its hub. This backbone service, aptly described as *Bus Rapid Transit*, is characterized by several features that enable Curitiba's bus service to approach the speed, efficiency, and reliability of a subway system:

- integrated planning
- exclusive bus lanes
- signal priority for buses
- pre-boarding fare collection
- level bus boarding from raised platforms in tube stations
- free transfers between lines (single entry)
- large capacity articulated and bi-articulated wide-door buses
- overlapping system of bus services

Each artery is composed of a "trinary" road system, consisting of three parallel routes, a block apart. The middle route is a wide avenue with "Express" bus service running down dedicated high-capacity express busways in the center two lanes, offering frequent stop service using standard, articulated and bi-articulated buses carrying up to 270 passengers apiece. The outer lanes are for local access and parking. Back in the 1960s the building of a light rail system in these avenues had been considered, but proved to be too expensive. The two outer routes are one-way streets with mixed vehicle traffic lanes next to exclusive bus lanes running "direct" high-speed bus service with limited stops. Both the express and direct services use signal priority at intersections.

Buses running in the dedicated and exclusive lanes stop at tube stations. These are modern design cylindrical-shaped, clear-walled stations with turnstiles, steps, and wheelchair lifts. Passengers pay their bus fares as they enter the stations, and wait for buses on raised station platforms. Instead of steps, buses are designed with extra wide doors and ramps which extend when the doors open to fill the gap between the bus and the station platform. The tube stations serve the dual purpose of providing passengers with shelter from the elements, and facilitating the efficient simultaneous loading and unloading of passengers, including wheelchairs. A typical dwell time of only 15 to 19 seconds is the result of fare payment prior to boarding the bus and same-level boarding from the platform to the bus.

Passengers pay a single fare equivalent to about 40 cents (U.S.) for travel throughout the system, with unlimited transfers between buses. Transfers are accomplished at terminals where the different services intersect. Transfers occur within the prepaid portions of the terminals so transfer tickets are not needed. In these areas are located public telephones, post offices, newspaper stands, and small retail facilities to serve customers changing buses.

Ten private bus companies provide all public transportation services in Curitiba, with guidance and parameters established by the city administration. The bus companies are paid by the distances they travel rather than by the passengers they carry, allowing a balanced distribution of bus routes and eliminating the former destructive competition that clogged the main roads and left other parts of the city unserved. All ten bus companies earn an operating profit.

The city pays the companies for the buses, about 1 percent of the bus value per month. After ten years, the city takes control of the buses and uses them for transportation to parks or as mobile schools. The average bus is only three years old, largely because of the recent infusion of newly designed buses, including the articulated and bi-articulated buses, into the system.

3.3 Integration of Transit with Land Use Planning

Curitiba’s Master Plan integrated transportation with land use planning, with the latter as the driving force, and called for a cultural, social and economic transformation of the city. It limited central area growth, while encouraging commercial growth along the transport arteries radiating out from the city center. The city's central area was partly closed to vehicular traffic, and pedestrian streets were created. The linear development along the arteries reduced the traditional importance of the downtown area as the primary focus of day-to-day transport activity, thereby minimizing congestion and the typical morning flow of traffic into the central city and the afternoon outflow. As a result, during any rush hour in Curitiba, there are heavy commuter movements in both directions along the public transportation arteries.

The Master Plan also provided economic support for urban development along the arteries through the establishment of industrial and commercial zones and mixed-use zoning, and encouraged local community self-sufficiency by providing each city district with its own adequate education, health care, recreation, and park areas. By 1992, almost 40 percent of Curitiba's population resided within three blocks of the major transit arteries.

Other policies have contributed to the success of the transit system, in the areas of zoning, housing development, parking and employer-paid transit subsidies. Land within two blocks of the transit arteries has been zoned for mixed commercial-residential uses. Higher densities are permitted for office space, since it traditionally generates more transit ridership per square foot than residential space. Beyond these two blocks, zoned residential densities taper with distance from transitways. Land near transit arteries is encouraged to be developed with community-assisted housing. The Institute of Urban Research and Planning of Curitiba (IPPUC), established in the 1960s to oversee implementation of the Master Plan, must approve locations of new shopping centers. They discourage American style auto-oriented shopping centers by channeling new retail growth to transit corridors. Very limited and time-restricted public parking is available in the downtown area, and private parking is very expensive. Finally, most employers offer transportation subsidies to workers, especially low-skilled and low-paid employees, making them the primary purchasers of tokens.

3.4 Staged Development of the Bus System

As the population increased during the period from 1970 through the present, Curitiba's bus system evolved incrementally. It required expansion of service routes, frequencies, and capacities, and improvements in fare payment, scheduling, and facility design to facilitate the passenger transferring process. Innovative low-cost and low-tech options for new services and features were chosen over more expensive alternatives at each stage. Planners did not hesitate to abandon choices that did not work in favor of more effective solutions.

At several points throughout the bus system development, the option of constructing a rail network was considered. Initially, buses were chosen over rail because they were far more adaptable and cheaper for a developing city such as Curitiba. In the mid-1980s the ridership had grown enough to support a rail network, but capital costs were prohibitive. Instead, the high capacity, high speed service known as "direct" service was eventually introduced on the one-way exclusive bus lanes that parallel the main corridors one block away. This service, including the tube stations, cost about $200,000 per kilometer to build, and was far cheaper, faster and less disruptive than the estimated $20 million per kilometer for a light rail system.

Not to be underestimated in the evolution of the transit system is the influence of the current governor of the State of Parana, Jaime Lerner. Lerner left his position as president of the IPPUC to become a three-time Mayor of Curitiba, and then governor. With a stake in the development of the Master Plan, he was its champion throughout the years, providing guidance, a firm governmental commitment to transit, and leadership. His steady promotion of the plan enabled it to withstand any tendencies for local politics to alter its course.

3.5 Results of Bus Rapid Transit

The popularity of Curitiba's Bus Rapid Transit system has effected a modal shift from automobile travel to bus travel, in spite of Curitibanos' high income and high rate of car ownership relative to the rest of Brazil. Based on 1991 traveler survey results, it was estimated that service improvements resulting from the introduction of Bus Rapid Transit had attracted enough automobile users to public transportation to cause a reduction of about 27 million auto trips per year, saving about 27 million liters of fuel annually. In particular, 28 percent of direct bus service users previously traveled by car. Compared to eight other Brazilian cities its size, Curitiba uses about 30 percent less fuel per capita, because of its heavy transit usage. The low rate of ambient air pollution in Curitiba, one of the lowest in Brazil, is attributed to the public transportation system's accounting for around 55 percent of private trips in the city.

Residential patterns changed to afford bus access on the major arteries to a larger proportion of the population. Between 1970 and 1978, when the three main arteries were built, the population of Curitiba as a whole grew by 73 percent, while the population along the arteries grew by 120 percent. Today about 1,100 buses make 12,500 trips per day, serving more than 1.3 million passengers per day, 50 times more than 20 years ago. Eighty percent of the travelers use either the express or direct bus service, while only 20 percent use the conventional feeder services. Plans for extending the rapid bus network will reduce the need for conventional services. In addition to enjoying speedy and reliable service, Curitibanos spend only about 10 percent of their income on travel, which is low relative to the rest of Brazil.

4.0 APPLICATIONS OF BUS RAPID TRANSIT IN THE UNITED STATES

4.1 Planning for Bus Rapid Transit

The Federal Transit Administration (FTA) encourages U.S. cities to consider, analyze, and evaluate the benefits of implementing Bus Rapid Transit. Implementation of Bus Rapid Transit in the United States begins with the metropolitan planning process, which provides a forum for the development and evaluation of strategies to meet mobility needs at the regional level. Bus operations planning is generally the responsibility of the local transit operator, in cooperation with regional transportation planning agencies such as metropolitan planning organizations (MPOs). Consequently, several low-cost *operational* strategies -- including many improvements associated with Bus Rapid Transit -- may be evaluated and implemented by transit operators to improve the efficiency of their existing bus service. Where the multimodal transportation planning process determines that some type of major transportation *capital* investment (such as a fixed transit guideway/busway and/or passenger boarding facilities) may be required to meet the mobility needs in a given corridor, an analysis and evaluation of potential alternatives to meet these needs is typically undertaken.

Corridor planning for Bus Rapid Transit should incorporate community participation. Bus Rapid Transit should be analyzed and evaluated in relation to locally-defined goals and objectives for the transportation system, mobility needs, and the relative advantages, disadvantages and costs of alternative approaches to meeting those needs. Curitiba-style Bus Rapid Transit may be introduced as a capital investment option. A variety of enhanced bus elements also may be considered, depending on local concensus. Determination of the effectiveness of specific applications of Bus Rapid Transit will require consideration of multiple criteria:

- ***Mobility--*** access to employment, services, and facilities; bus travel time savings; impacts on traffic operations; increases in bus ridership

- ***Environmental Impacts*** -- reduced use of private vehicles and attendant air pollution; impacts on water resources and wetlands, parks and open spaces, and historical and cultural resources.

- ***Land Use*** -- compatibility with local land use policies, contribution to economic development

- ***Costs*** -- total project cost and measures of cost-effectiveness, including, for example, operating and capital cost per passenger or cost per passenger mile for each alternative under consideration; funding availability.

Following the selection of Bus Rapid Transit as the preferred solution in a multimodal analysis, proposed capital improvements need to be incorporated into the financially-constrained regional long-range transportation plan, developed by the MPO in cooperation with local transportation agencies and communities. More detailed engineering and completion of required environmental documentation would be necessary before Federal funding could be made available and construction could begin. FTA rates projects competing for its discretionary capital resources and recommends to Congress those projects which best justify continued Federal investment. Consequently, low-cost, high-performance Bus Rapid Transit projects that emerge from a locally-managed, multimodal analysis of alternatives may rate favorably in both local *and* Federal evaluations of potential transportation investments.

4.2 Implementation: Bus Rapid Transit Features

Many of the features of the Curitiba experience may be directly transferable to the U.S.; others may be applicable in concept only. For example, signal priority for buses moving along city streets could be implemented by many U.S. cities, but cashless fare collection methods during passenger boarding, rather than pre-boarding fare collection as in Curitiba, may be more feasible in some U.S. cities for reducing dwell time at bus stops. Features that are likely to be applicable to U.S. implementations of Bus Rapid Transit include the following:

- ***Exclusive bus lanes*** -- may be separated from automobile lanes by barriers, or simply signage and road markings. On city streets, there are several ways these can be implemented. A two-way street might have one exclusive bus lane in each direction, while a one-way street might have one dedicated lane. The bus lanes might be the outside lanes of a two-way street, or, as in Curitiba, the two center lanes. In older cities with narrow street patterns, the dedication of an entire street to bus traffic is a possibility.

  On highways, exclusive bus lanes can be installed in each direction, and separated from other traffic by barriers or signage. Often these lanes will fit into median strips, rather than decrease the number of lanes available for automobiles. Where space is constrained, one exclusive bus lane could change direction to coincide with the rush hour traffic flow.
- ***Traffic signal priority for buses*** -- eliminates delays in bus service due to excessive waits at

intersection signals. There are two general types of systems. In the first, depending on the program algorithm, a bus approaching a downstream traffic signal extends the green light or advances the cycle to green, either through transponders or other electronic communications means, to proceed through the intersection. The bus operator determines when signal priority is needed to maintain the bus schedule. In the second, a bus system equipped with an automatic vehicle location (AVL) system and advanced radio communications gives signal priority control to the operations center, where typically a computerized system determines bus adherence to schedule and automatically triggers traffic signals when needed.

On streets with exclusive bus lanes, signal priority can be used when needed to give buses a head start over the rest of the traffic (a queue jump) by adding a signal phase that advances the green light for the bus lane prior to the green light for the other traffic lanes.

- ***Fare collection system that speeds up the boarding process*** -- would decrease dwell time and improve overall system efficiency. A subway-like solution is the prepayment of fares prior to boarding, as in Curitiba's tube stations. However, the amount of space required to accommodate and secure prepaid customers waiting for buses may prohibit this option on many American city streets. Cashless fare payment methods that customers use as they board, such as prepaid passes, credit cards and "smart" cards, are likely more appropriate for most U.S. transit operations.

- ***Same-level boarding platform and bus floor*** -- would speed up the boarding and deboarding processes, especially where wheelchair-bound passengers are involved. Such a feature would help bring a U.S. transit system into compliance with the Americans with Disabilities Act. There are two options here: buses with low floors that are even with the curbside, and loading platforms that bring passengers level with the floors of stairless buses. Innovative bus stop designs could incorporate accessibility as an integral element for use not only by disabled passengers, but the general riding public.

- ***Effective, clearly designated off-street facilities to handle increased numbers of buses in the central business district*** -- will ease congestion, provide visibility for bus services, and increase the efficiency and safety of boarding operations that do not have to compete with city traffic. Cities with central business districts concentrated in a small geographical area would generate enough local passengers to make off-street bus terminals effective. Terminals might feature convenient passenger services, such as newspaper stands, dry cleaning and film drop-off counters, and stamp machines. Bus malls might provide circulator service on bus-only streets through the central business district, and connect bus terminals at opposite ends of the district.

- ***Hierarchical system of services*** -- would build upon the high speed bus service to offer a broad network of services (feeder, direct, express and/or circulator buses) covering an entire metropolitan area. The system would be characterized by ease of transfer between services with regard to fare payment and passenger-friendly signage and identification of bus routes and schedules. Such a system would have the capability of linking suburb to suburb as well as suburb to downtown, setting the stage for changes in land use policy.

- ***Supportive land use policy*** -- including zoning regulations and master planning can promote high density development along transit corridors and in central cities and other commercial or neighborhood centers. Compact development will not only encourage use of Bus Rapid Transit, but promote the vitality of communities and local business districts and reduce automobile use, urban sprawl, pollution and energy consumption.

4.3 New Technology in Bus Rapid Transit

New Intelligent Transportation Systems (ITS) or Advanced Public Transportation Systems (APTS) applications could contribute to improved bus service and increased bus operating speeds. Some ITS and APTS applications that a Bus Rapid Transit system might employ are described below, but this list is by no means exhaustive:

- ***"Smart" card fare collection methods*** -- use read-and-write technology to store dollar value on a microprocessor chip inside a plastic card. As passengers board a bus, the card reader determines the card's value, debits the appropriate amount for the bus ride, and writes the balance back onto the card, all within a fraction of a second. There are two types of card readers, the proximity reader which can read cards held a few inches away, and the contact reader which requires physical contact with a card. Under development are systems that will be able to read cards carried in passengers' pockets, wallets and purses. Cashless systems such as "smart" cards speed up the fare collection process and eliminate expensive cash handling operations at transit agencies.

"Smart" cards can also be programmed for distance-based pricing by recording where a passenger enters a transit system and debiting the appropriate amount from the card balance according to the point where the passenger exits the system, regardless of the number of internal transfers.

- ***Automatic vehicle location (AVL) systems*** -- enable transit agencies to track their vehicles in real time and provide them with information for making timely schedule adjustments and equipment substitutions. AVL systems are computer-based vehicle tracking systems that measure the actual real time position of each vehicle, and relay the information to a central location. The measurement and relay techniques vary, but the most common are: signpost and odometer, wherein a receiver on a bus detects signals sent by signposts along the bus route and transmits the identity of the signpost and the odometer reading to the control center; and Global Positioning Satellite (GPS) technology, wherein an onboard GPS receiver determines the bus position and transmits the information to the control center. AVL systems can be augmented by geographical information systems (GIS) on control center computers that display the location of the vehicles on route map grids.

- ***Computer-aided dispatching and advanced communications*** -- are systems that enable transit dispatchers, in combination with AVL systems, to maintain bus system efficiency by performing service restoration activities and communicating instructions to and receiving messages from drivers. Service restoration activities include such operations as adjusting dwell times at bus stops or transfer points, adjusting vehicle headways, rerouting vehicles, adding buses to routes, and dispatching new vehicles to replace disabled vehicles. Communications can be received in buses via radiotelephones, cellular telephones, or mobile display terminals.

- ***Precision docking at bus stops*** -- uses sensors on buses and on the roadside to indicate the exact place where the bus should stop. Bus doors opening at the same location each time make it possible for passengers to be in position for immediate boarding once a bus has stopped, shortening dwell time.

- ***Tight terminal guidance*** -- uses sensors similar to those for precision docking to assist buses in maneuvering in terminals with limited space. This type of system can help minimize the amount of space needed for bus terminal operations, as well as reduce the overall amount of time a bus spends at terminals.

- ***Warning systems*** -- are beginning to appear on the market to assist the bus driver in a number of safety areas: collision avoidance, pedestrian proximity warning, attentive driver monitoring and warning, intersection collision avoidance, and low tire friction warning. Safety improvements can help any bus system increase its reliability and efficiency by reducing the likelihood of accidents and incidents.

- ***Passenger information systems*** -- give passengers the means to make informed decisions about their transit travel. Of the many technologies now available for passengers to access this type of information, the APTS applications most appropriate for Bus Rapid Transit are in-vehicle information systems. These systems automatically announce approaching bus stops, allowing disembarking riders to position themselves near the doors prior to arriving at their stops, and speeding up the unloading and loading operation.

- ***Automated enforcement systems for exclusive bus lanes*** -- are being enhanced by new technology, including automatic video cameras and infrared sensors. These state-of-the-art systems are just now appearing on the commercial market.

4.4 Effects of Bus Rapid Transit

Successful Bus Rapid Transit systems can be expected to produce improvements in bus service, operations, and ridership, and to affect traffic congestion and air quality:

- ***Bus speeds and schedule adherence***: Perhaps the most fundamental effect of a Bus Rapid Transit system, travel times would likely improve due to the lack of impediments to bus movement along exclusive bus lanes. Bus speeds would be expected to improve not only in absolute terms, but also relative to the automobile traffic that parallels the exclusive lanes.

- ***Ridership***: Ridership would be expected to increase due to improved bus speeds and schedule adherence. Customers who use buses infrequently might ride more often, and some automobile users might convert to transit. A visible improvement in bus speeds might be noticeable to drivers of other vehicles, presenting a positive image of transit as an alternative to driving.

- ***Other traffic***: If the creation of exclusive bus lanes reduces the number of lanes available for other traffic, then in the short term the possibility of increased congestion on the roadways is raised. Traffic flow on cross streets and turning traffic may be disrupted as buses use their signal priority to travel uninterrupted through intersections. Further, mobility on alternate routes may deteriorate, as drivers seek ways to avoid roads with exclusive bus lanes. One of the challenges of implementing an exclusive bus lane would be to minimize this disruption.

- ***Air quality***: Long term, as ridership increases and the overall level of general-purpose traffic decreases, urban areas may experience improved air quality due to reduced emissions from automobiles.

5.0 SUMMARY AND CONCLUSIONS

The example of Curitiba, Brazil and experience in the U.S. illustrate the potential of improved bus services to address mobility needs in metropolitan areas. Buses provide flexible and cost-effective public transportation. Metropolitan areas throughout the U.S. can build on the experience of Curitiba and other cities to develop Bus Rapid Transit systems that provide fast, reliable, and convenient service in cities and suburbs.

Upgrading the performance of bus services to meet the objectives of Bus Rapid Transit will require policies that give priority to bus operations and provide for investment in crucial system components: infrastructure that separates bus operations from general-purpose traffic; facilities that provide for increased comfort and system visibility; and technology that provides for faster and more reliable operations. New guidance, information, and fare technologies offer an expanded range of possibilities for operating bus systems that have the potential to produce marked improvements in performance, surpassing previous standards and changing public perceptions of bus service. High-quality bus operations have the potential to create new, improved land use options that provide for compact, pedestrian-friendly and environmentally-sensitive development patterns that preserve neighborhoods and open space. Bus Rapid Transit thus will have maximum benefit when developed in close coordination with land use policies and community development plans.

Implementation of Bus Rapid Transit poses a number of challenges, ranging from the need for adequate cross sections on city streets to provide separate rights-of-way for buses, to maintaining the quality of general-purpose traffic flow and minimizing local noise and air quality impacts. These challenges require detailed analysis in the context of specific local applications to identify appropriate solutions and to determine where Bus Rapid Transit can have the greatest benefit. Bus Rapid Transit is a concept that merits widespread evaluation and consideration as an adaptable, effective public transportation alternative to automobiles that has the potential to meet a broad range of mobility needs and support an improved quality of life in U.S. metropolitan areas.

ACRONYMS

APTS	Advanced Public Transportation Systems
AVL	Automatic Vehicle Location
DOT	Department of Transportation
FTA	Federal Transit Administration
GPS	Global Position System
HOV	High-occupancy Vehicle
IPPUC	Institute of Urban Research and Planning of Curitiba
ITS	Intelligent Transportation System
MPO	Metropolitan Planning Organization
U.S.	United States
Volpe Center	Volpe National Transportation Systems Center

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