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From Buses to BRT: Case Studies of Incremental BRT Projects in North America, MTI Report 09-13

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From Buses to BRT: Case Studies of Incremental BRT Projects in North America

MTI Report 09-13

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FROM BUSES TO BRT: CASE STUDIES OF INCREMENTAL BRT PROJECTS IN NORTH AMERICA

June 2010

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16. **Abstract**

Bus Rapid Transit (BRT) uses different combinations of techniques to improve service, such as bus-only lanes and roads, pre-boarding fare collection, transit priority at traffic signals, stylish vehicles with extra doors, bus stops that are more like light rail stations, and high frequency service. This study examines five approaches to BRT systems as implemented by public transit agencies in California, Oregon, and Ontario.

The case studies as a group show that BRT can be thought of as a discretionary combination of elements that can be assembled in many different combinations over time. Every element incrementally adds to the quality or attractiveness of the service. This latitude provides transit agencies with many benefits, including the ability to match infrastructure with operating requirements. For example, a BRT service can combine operations serving free flowing arterial roads in the fringes of the downtown with dedicated lanes in areas closer to city center where congestion is greatest. Buses can operate both on and off the guide way, extending the corridors in which passengers are offered a one-seat ride with no transfer required. Transit agencies also can select specific BRT components and strategies, such as traffic signal priority and increased stop spacing, and apply them to existing local bus operations as a way to increase bus speeds and reduce operating costs.

The specific elements selected for a BRT route can be implemented all at once, or in incremental stages—either or both geographical extensions or additions of features. All of the case studies showed ridership improvements, but the Los Angeles Metro Rapid bus system illustrates the wide geographic coverage, improved ridership, and moderate cost per new rider that is possible with an approach that includes fewer BRT features spread over more miles of route. Quantitative results from the case studies suggest that incremental improvements, applied widely to regional bus networks, may be able to achieve significant benefits at a lower cost than substantial infrastructure investments focused upon just one or a few corridors.

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Valuable data and insight were provided to report authors Niles and Jerram by all other team members. Particularly noteworthy, Ganther and Madou provided field observation reports on bus transit operations in California that were important supplements to the documented information the authors primarily relied upon.

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The report integrates data from many sources and makes numerous critical interpretations. Any opinions and conclusions expressed are those of the lead author Niles, but also were significantly influenced by discussions with all the team members.

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EXECUTIVE SUMMARY

Bus Rapid Transit (BRT), as illustrated in implementations around North America, comes in many shapes and sizes. The term has been applied to rubber-tire transit lines that use many different combinations of techniques to improve bus service, such as bus-only lanes and roads, pre-boarding fare collection, transit priority at traffic signals, stylish vehicles with extra doors, bus stops that are more like light rail stations, and high frequency service.

This study examines five approaches to BRT systems as implemented by public transit agencies in California, Oregon, and Ontario. The resulting lines and network of lines vary widely, ranging from small changes in a local bus route, to a completely new line in a new mode. On one end of the spectrum, the San José area has frequent arterial bus services with traffic signal priority. On the other end, we describe the case of a transit-only, grade-separated busway in Los Angeles County with full-featured stations and special buses that look like no others in the agency. The authors also describe three variations more in the middle of the range of BRT possibility.

The case studies as a group show that BRT, as applied in North America, is a discretionary combination of elements that can be assembled in many different combinations over time. Transit agencies have wide latitude to determine which combination of elements best serves their needs, given their specific circumstances. Every element incrementally adds to the quality or attractiveness of the service.

This latitude provides transit agencies with many benefits, including the ability to match physical infrastructure with operating requirements. For example, a BRT service can combine operations serving free flowing arterial roads in the fringes of the downtown with dedicated lanes in areas closer to city center where congestion is greatest. Moreover, unlike rail transit, bus transit vehicles can operate both on and off the guide way, extending the corridors in which passengers are offered a one-seat ride with no transfer required. Transit agencies also can select specific BRT components and strategies, such as traffic signal priority and increased stop spacing, and apply them to existing local bus operations as a way to increase bus speeds and reduce operating costs. Indeed, this strategy was used by one of the case study locations—the Los Angeles Metro Rapid system.

This latitude also creates challenges. For example, as shown by the case studies overall, a wide range of systems are labeled as BRT in North America, creating confusion among policymakers and the public regarding the definition of BRT. By contrast, in other parts of the world, such as Latin America and Asia, the term BRT is more frequently understood to be a rail-like rapid transit system with fully dedicated lanes and trunk and feeder operations. Thus, a basic bisection of BRT implementations into heavy and light is useful, depending on the degree of exclusivity of the guide way. Heavy BRT means the buses are mostly running on lanes separated from other traffic, and light BRT means the buses are mostly operating in mixed traffic.

The wide range of options creates planning challenges. When does the expense and construction time of a dedicated lane or guide way pay off in higher performance and, if so, over what portions of the route should such infrastructure be implemented? If a dedicated guide way is used, will it be used by special buses as a trunk line with stations reached by other modes, or will the guide way be an HOV lane open to other vehicles that can operate off-guide way, including local buses, van pools, taxis, and car pools? Can the overall travel time benefits of a dedicated lane be achieved at substantially lower cost by other means, such as increased station spacing and traffic signal priority, especially if these are applied widely across a bus system, rather than in just a single corridor?

Across the various BRT elements falling into the categories of guideway, stations, vehicles, technology, and operations pattern, the specific elements selected for a BRT route can be implemented all at once, or in incremental stages. Increments can be either or both geographical extensions or additions of features.

This flexibility has substantial policy implications in the expanded choices for transit investment that are available. The transportation sector accounts for nearly one-third of carbon dioxide emissions in the United States. Achieving President Obama's goal of an 80 percent reduction in emissions by 2050 will require fundamental changes in transportation planning and delivery, including ensuring that many more urban travelers have viable public transit options.

Bus performance improvement offers quick results at a reasonable public cost. For example, as shown by the case studies, the 26 bus lines of the Los Angeles Metro Rapid network were implemented far more quickly and for billions of dollars less than the four L.A. rail lines, yet these enhanced buses are serving 78 percent as many passenger trips as the entire rail system. All of the Metro Rapid lines even cost less to put in place than the single Orange Line BRT line in the same city, and yet the Metro Rapid is providing over three times the gain in daily boardings. These examples suggest that incremental improvements, applied widely to regional bus networks, may be able to achieve significant benefits at a lower cost than substantial infrastructure investments focused upon just one or a few corridors.

The following table—the same as Table 19 in the main text—summarizes several performance characteristics of the case studies described in this report. All of the case studies showed ridership improvements, but the figures in the far right hand column for the L.A. Metro Rapid system illustrate the wide geographic coverage, improved ridership, and moderate cost per new rider that is possible with an approach that includes fewer BRT features spread over more miles of route.

Table 1 Performance of Five BRT Development Experiences

	L.A. Metro Orange Line Median busway with TSP	Lane County EMX Green Line Median busway with TSP	York Viva On-street running with TSP	VTA Route 522 Rapid On-street running with TSP	L.A. Metro Rapid On-street running with TSP
Travel time reduction, percent	16%	6%	11%	20%	25%
Baseline corridor ridership pre-BRT	41,580 (2005)	2,700	19,400	18,023	388,400 (2000)
Cited corridor ridership after BRT implementation	62,597 (2007)	5,400	45,000	21,300	464,400 (2007)
Corridor ridership increase	21,017	2,700	25,600	3,277	76,000
Ridership percentage increase	51%	100%	132%	18%	20%
Capital investment cost (millions)	$350	$24.5	CA$172	$3.5	$110
Route miles	13.5	4	50	26	450
Cost per mile (millions)	$26	$6.1	CA$3.4	$0.13	$0.24
Cost per new daily rider	$16,700	$9,100	CA$6,600	$1,100	$620

Source: Case study data in this report. TSP means transit signal priority

As reflected in federal law, the Federal Transit Administration's capital grants program—New Starts—requires corridor-level development, as opposed to system-wide improvements. There is no provision for a jurisdiction to consider, as part of the alternatives analysis process, whether the level of funding for a major corridor-level project could achieve even greater benefits if applied to more modest system-wide improvements.

The case studies in this report show that BRT is not a one-size-fits-all solution, but rather a wide range of strategies that can be deployed in specific corridors or across entire bus systems. The availability of BRT elements in many incremental combinations suggests that an expanded policy framework is warranted: one that enables objective comparison across these options and the allocation of funding to projects that achieve the greatest benefit at the lowest cost.

INTRODUCTION

Concerns about traffic congestion, high fuel prices, national energy security, climate change, air pollution, urban competitiveness, and quality of life underpin a strong interest in new public transportation investments. The American Public Transportation Association (APTA) reports that 72 percent of transit tax issues passed in the election of November 4, 2008.[1] In recent years, the U.S. Federal Transit Administration (FTA) has been inundated with applications for projects seeking grant funding, causing the New Starts program to become extremely competitive. This environment is forcing many cities to look for innovative, cost-effective options to enhance public transportation services.

In recent years, bus rapid transit (BRT) has become a popular option. BRT encompasses a wide range of meaning. The term has been applied to many combinations of elements that yield better bus service, ranging from frequent arterial bus services with signal priority to fully dedicated, grade-separated busways. This broad menu offers flexibility in planning and implementation, but also has created confusion about exactly how BRT should be defined. Under federal rules for the New Starts program (Section 5309), a BRT project must encompass a dedicated right-of-way to be eligible for funding, which can mean bus-only lanes on an arterial that are shared intermittently with private vehicles making an immediate turn off the arterial.

Beginning in 2007, because of the addition of Small Starts and Very Small Starts to the FTA's funding pipeline, there have been more BRT projects in development than light rail or commuter rail projects.[2]

The growing recognition of BRT as an option for transit improvement is a paradigm-shifting development. But given the flexibility and cost-effectiveness of BRT, what are the best strategies to maximize the benefit of a BRT investment, with or without a federal contribution? For example, should a community make modest improvements to several high-demand bus routes, or is it better to focus a larger investment on a single corridor, such as by building a dedicated busway?

The aim of this project has been to uncover and analyze existing agency BRT implementation steps and strategies in order to identify innovations that could incrementally upgrade bus service throughout a network toward better performance and attracting more riders.

WHAT IS BRT?

Bus Rapid Transit (BRT) has been comprehensively characterized and described in recent reports from the Transit Cooperative Research Program (TCRP).[3] BRT comes across in these reports—and in actual practice as well—as an urban bus service at a higher than usual quality level.

BRT is typically deployed one route at a time after several years of development. A BRT route is characterized by a set of features meant to increase the reliable point-to-point speed of bus travel in urban settings throughout the day. At the same time, a BRT route and its coaches usually present an attractive, distinctive visual image to customers.

As pointed out in TCRP 90, the main feature set of BRT includes “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.” ITS stands for “intelligent transportation systems” and refers to applications of computers and wireless communications. The most common ITS applications are transit signal priority (TSP), automatic vehicle location (AVL), automated scheduling and dispatch, and electronic displays of real-time information about bus locations at stations and aboard the coaches.
In this study, the authors have sought to challenge presumptions and add value to the

In this study, the authors have sought to challenge presumptions and add value to the *BRT Practitioners Guide* (TCRP 118), especially Chapter 5: System Packaging, Integration, and Assessment. As the *Guide* notes: “All BRT systems will have running ways, stations, and vehicles. The types of these features, as well as the types of various ITS-related components, will depend upon local needs, conditions, attitudes, and resources.” The authors provide case studies that illustrate the truth of this statement, but we have also sought to bring out the local needs, conditions, attitudes, and resources that lead to variations in BRT around North America.

As will be illustrated in the case studies, some jurisdictions approach BRT as a high-quality, fixed-route transit mode to attract transit-oriented development around station stops for compact growth and economic development. Private vehicle parking is typically somewhat restricted in such development and the availability of transit as an access alternative is seen as a form of congestion mitigation. While the heavy BRT investments among the case studies below have been associated with commercial and multi-family residential development,[4] the lower cost investments in other case studies are not focused on this outcome. Overall, the researchers’ hypothesis is that bus service can be made better for urban mobility at both high and low levels of investment, with the implicit understanding that land use changes may not be evident from the light BRT systems that result.

A SHORT HISTORY OF BRT

The term “bus rapid transit” first appeared in a 1937 public transit plan for Chicago, a time just prior to World War II when buses were rapidly replacing street railways across urban America.[5] City-specific BRT plans and conceptual overview studies appeared sporadically in the 1950-through-1980 period as the Interstate highway system was being built, including many freeways in urban areas. Several pre-1980 BRT systems had buses running on freeways. Many present-day concepts of BRT were laid out in study documents produced by 1970.[6]

A few exclusive busways were built in some U.S. cities in the 1970s, and some of these guideways were made more productive for intermodal movement of people subsequently by allowing private HOVs to intermix with buses.[7] The start of heavy rail subway construction in the Washington DC, Atlanta, and San Francisco Bay Area urban regions in the early 1970s, plus the surge of light rail interest and construction funded by the U.S. DOT starting in the late 1970s, established a rail-centric trend on modal choice through the 1980s and 90s.[8]

But in the last decade of the 20th century, the successful performance of prominent BRT systems in Curitiba, Brazil and Ottawa, Canada, combined with the rising cost of rail systems in America, led to a Federal Transit Administration BRT demonstration program. South American BRT was initially a reaction to the high cost of subways. Curitiba's system was characterized as an "above ground subway" or "train on rubber tires" built instead of a rail system, with station and exclusive guideway concepts later elaborated in another system begun a decade later in Bogota, Colombia.

The BRT concept as developed just before and after the beginning of the 21st century was motivated by federal interest in a lower priced alternative to light rail that worked approximately as well. As Alan Hoffman points out, BRT has become to be understood in North America as "light rail lite."[9]

First-generation BRT in the United States has tended to be corridor-focused, seeking in initial conception to be a nearly train-like implementation of high-capacity trunk lines as a substitute for urban mass transit railways. However, this ideal did not always materialize and variations quickly developed.

A distinction that has lately developed in practice is the division of BRT routes into *heavy BRT*, or "real BRT," vs. *light BRT* or Rapid Bus. The distinction depends mostly on the degree of exclusivity of the running way. Heavy BRT means the route has a busway that does not allow other kinds of traffic, although in some cases there are at-grade crossings for other types of vehicles. The separation of transit from automobile traffic is considered the gold standard in bus transit network design.

Light BRT implies bus routes that are subject to speed as permitted in a mixture of vehicle traffic. If that other traffic is moving smoothly at posted speeds, so too the buses in the mixture also move well, but at a pace determined by how often and for how long they need to dwell at bus stops for passengers to board or exit. Available techniques for buses to gain an advantage in traffic congestion include bus-only queue jump lanes at intersections and authorization to operate on a breakdown shoulder.

PROBLEMS AND ISSUES THAT BRT ADDRESSES

Consideration of the fundamental design characteristics of BRT suggests several areas where it offers the prospect of a better ratio of resources consumed to results achieved—the productivity ratio.

Bus Rapid Transit is designed to provide faster, more reliable, and more comfortable bus service in urban settings. As shall be seen in the case studies described below, these performance characteristics, along with more visually appealing vehicles, tend to attract more passengers than the traditional bus services that are replaced or supplemented by BRT.

While light rail is frequently more politically attractive than improved bus service, BRT can be more quickly implemented and at lower cost than rail alternatives. BRT is sometimes held out as an intermediate step in the conversion of a bus-served transit corridor to a light rail alignment. Sound Transit in Seattle, Washington, has advanced the concept of "rail-convertible BRT,"[10] which includes building an exclusive guideway for buses on which tracks can be laid down later. In one of the case study jurisdictions described in this report, York, Ontario, street-running light rail where the BRT now runs is officially discussed as a future option.

With soaring energy costs and rising transit demand, transit agencies need to find ways of increasing the productivity of service delivery, in other words, improving the ratio of results to resources. This means more service and ridership for existing resource levels, or reducing the resources required for a present level of service so that service can be increased elsewhere. Since every rider on urban public transit is subsidized, achieving improved productivity is critical in a time of rising transit demand. Better productivity allows a transit agency to gain ridership at a decreasing cost per rider, which would allow transit ridership to grow without a proportional rise in costs.

Larger, multi-door BRT buses coming more often can be a source of productivity gain. An example comes from the new Euclid BRT Line in Cleveland, Ohio. The transit management there forecast that the upgrade of the Number 6 line to a BRT service called HealthLine, which opened in late 2008. This upgrade will allows a shift of 16 drivers to carry more passengers than was achieved in the pre-BRT service configuration with 28 drivers.[11]

Even using the same buses and simply moving them along a route faster can mean reduced bus service hour for the same or greater number of passenger miles of service delivery. BRT routes carrying many passengers with faster end-to-end run times than traditional buses are a method for providing transit service with a lower cost per passenger mile and per boarding than non-BRT transit services.

At the same time, the faster speed and visual attractiveness of BRT potentially generates more political support for the taxpayer-funded subsidies that are necessary to operate public transit in North America.

EXISTING PARADIGM FOR BRT DEVELOPMENT

To date, best practice authorities have invariably recommended that development of BRT be focused on high-density, high-volume corridors. As the *Bus Rapid Practitioner's Guide* explains in Chapter 5, the first activity in the "general guidelines" is "identifying the appropriate corridors." This step, according to the *Guide*, is followed by evaluating alternatives for specific alignments within the chosen corridors, selecting alignments, and choosing the BRT components.

The *Guide* notes too that "BRT can be developed incrementally, with each stage keyed to demand characteristics and the availability of resources." The stages cover adding to or upgrading the elements of the starter system, or extending the geographic reach.
The case studies below conform to this developmental paradigm.

RESEARCH HYPOTHESES

The authors began this research project with intent to understand the full potential of BRT elements and strategies to improve transit agency performance when applied incrementally. They were aware that in Latin America and Asia, BRT is typically defined as a rail-like rapid transit system with fully dedicated trunk lanes, very long buses including double-articulated buses, enclosed stations that require payment to enter, and coordination with feeder operations using more traditional local buses.[12] The authors hypothesized that emphasizing BRT *only* as an integrated package of performance-enhancing elements was too narrow for the urban transit improvement opportunities on hand in North America. Preconceived notions that BRT needs all or most of the available elements to be successful may constrain consideration of the lower-cost performance improvement opportunities from implementing individual BRT elements.

The project has not been focused on mode choice between road and rail transit in a corridor, a choice that is sometimes invoked in discussions about BRT. Rather, the authors have tried to develop new findings, conclusions, and recommendations about how to use BRT characteristics to make bus service better across an entire service territory.

At the outset of the research, researchers were intrigued by what Levinson, Zimmerman, Clinger and Rutherford noted in the *Journal of Public Transportation* in 2002:

> Even where implementation of a comprehensive, integrated BRT system is not possible, many of its components can be adapted for use in conventional bus systems with attendant benefits in speed, reliability, and transit image/attractiveness.[13]

How can BRT components be applied widely to conventional bus systems?

CASE STUDIES OF NORTH AMERICAN BRT IMPLEMENTATION

The experience of four North American case study transit agencies in developing and deploying BRT illustrates that a range of approaches are possible.

The authors were motivated in the selection of case studies to illustrate a diversity of approaches that perhaps would open up an even wider viewpoint on strategies for improving bus service.

This study screened 13 transit agencies with BRT implementations in North America to identify four agencies with diverse, illustrative experiences and a commitment to ongoing bus service improvement. The four case study agencies ultimately selected illustrate five different approaches.

- York Region Transit (Toronto Region), Ontario, and Viva: Total system approach; complete revamp of regional system around light BRT corridors on key arterials, with conversion to rail possible later.
- Lane County Transit (Eugene), Oregon, EmX: Single-corridor light BRT; light rail emulation on a single route, with additional routes planned.
- Los Angeles County Metro, California, Metro Rapid: System-wide upgrade of multiple high-volume arterial routes with light BRT overlay routes
- Los Angeles County Metro, California, Orange Line: Single corridor heavy BRT based on a new right-of-way available.
- Santa Clara County Valley Transportation Authority (San José), California, VTA Rapid 522: Single-corridor light BRT overlay; further BRT routes possible.

YORK REGION VIVA BRT: SYSTEMWIDE BRT, BETWEEN LIGHT AND HEAVY

The York region is in southern Ontario, directly north of Canada's biggest city, Toronto. The region is a collection of suburban and rural communities, with the majority of its population clustered in the south near the Toronto border. The York region has about one million residents as of 2009[14] and is characterized by low-density development and high automobile dependence.[15]

York's BRT service, the Viva, opened in 2005. The Viva is a 50-mile BRT network along four corridors that connect the region's four main population centers. The network is overlaid onto the system of local bus routes, some of which were altered to feed riders to the Viva. York is implementing the Viva service in three phases. Phase I, known as Quick Start, instituted a high-capacity dedicated bus fleet, priority treatments, more widely spaced bus stops than the local routes have, enhanced stations, off-coach fare collection, schedule improvements, and extensive branding and marketing—all the elements of heavy BRT save one: the dedicated running way. By operating the BRT in existing roadways, York was able to build the system in just three years at a cost of $171 million (Canadian), or CA$3.42 million per mile.

Phase II, for which planning is underway as of 2009, will introduce dedicated on-street transitways and other service and infrastructure improvement. This second phase, known as vivaNext, also incorporates a planned extension of the subway from Toronto. Based upon results of a major system review, Phase III could include bus service extensions and conversion of some of the BRT lines to light rail.[16]

Project History and Goals

Both the incremental build-out strategy and the corridor-based transit network are central to the region's long-term land use management plan. Since 1971, York has experienced rapid population and employment growth. This growth has made York's sprawling, car-oriented land use pattern unsustainable in the eyes of regional officials, who are concerned about worsening traffic congestion and loss of green space.[17] To address these problems, York's Official Plan calls for a shift to a more urban style of development featuring high-density, mixed-use communities connected by rapid transit.

Prior to the Viva, York's primary transit option was an extensive network of local arterial bus routes, as well as peak-hour express buses and shuttles buses, owned and operated by York Region Transit (YRT). As of 2004, the year before Viva opened, YRT operated 81 routes and carried around 5.3 million passengers annually, according to the agency. York reports that ridership has increased more than 10 percent each year since 2001. York is also served by the provincial transit agency, GO Transit, which provides commuter rail and coach service into Toronto, as well as bus service to other parts of Southern Ontario. The Toronto Transit Commission (TTC) provides bus service connection to the TTC subway. The Region's official land use strategy designates the region's four biggest municipalities—Markham, Richmond Hill, Newmarket and Vaughan—for high-density, mixed-use development. These cities are linked by York's two main transportation corridors: Highway 7, the main east-west artery that runs adjacent to Toronto, and Yonge Street, which runs north-south from the border of Toronto to York's northernmost edge. To support concentrated development, the land use strategy and the Transportation Master Plan based upon it call for the creation of a network of dedicated transitways along these two main transportation corridors, connecting the four cities to each other, to the surrounding local bus service, and to rail service into Toronto. In addition to dedicated transitways, the plan calls for use of modern vehicles, ITS features, greater spacing between stations, extended service and pedestrian-friendly streetscapes. The Plan envisions creating a virtuous feedback loop whereby the new transit service encourages transit-oriented development (TOD) along the designated corridors, and, in turn, this TOD supports increased transit investment, which can attract more choice riders. York's goal is to increase peak hour transit travel from an 8 percent market share, where it stood in 1996, to 17 percent by 2031.[18]

When planning for this new transit network began, officials were faced with the challenge of building an entirely new system while meeting immediate transportation needs. Their solution was to build the system in stages, starting with all major BRT features except the most expensive and complex one—the dedicated transitway. An incremental build—out allows planners to improve service and address congestion problems in the near-term while establishing rights-of-way for, and building ridership to support, dedicated transitways in Phase II. This strategy has the added advantage of immediately establishing the desired transit use patterns that could attract compact, mixed-use development, as well as improving the image of transit for potential developers and new riders. York's incremental strategy also incorporates the option of converting the dedicated BRT lanes to light rail should future ridership demand warrant it.

Building Phase I of the Viva BRT

In this section, researchers examine the elements implemented in the Viva system and the cost for each.

Running Way Priority and Routing

The incremental build-out strategy saved time and money in building the system. Constructing a dedicated transitway requires acquiring rights-of-way, a costly and time-consuming process, and any land takings trigger the need for an Environmental Impact Statement, introducing a significant delay into the service deployment schedule.[19] Moreover, construction of dedicated running ways is very costly. The Federal Transit Administration's 2004 publication, *Characteristics of Bus Rapid Transit (CBRT)* report estimated that a median transitway—which YRT plans to build during Phase II—costs from U.S.$5 to $10 million per lane mile. Indeed, estimated cost for the Phase II rapidways is CA$2.8 billion, about ten times the cost of Phase I. YRT also projects that it will take around seven years to implement, much longer than Phase I.[20]

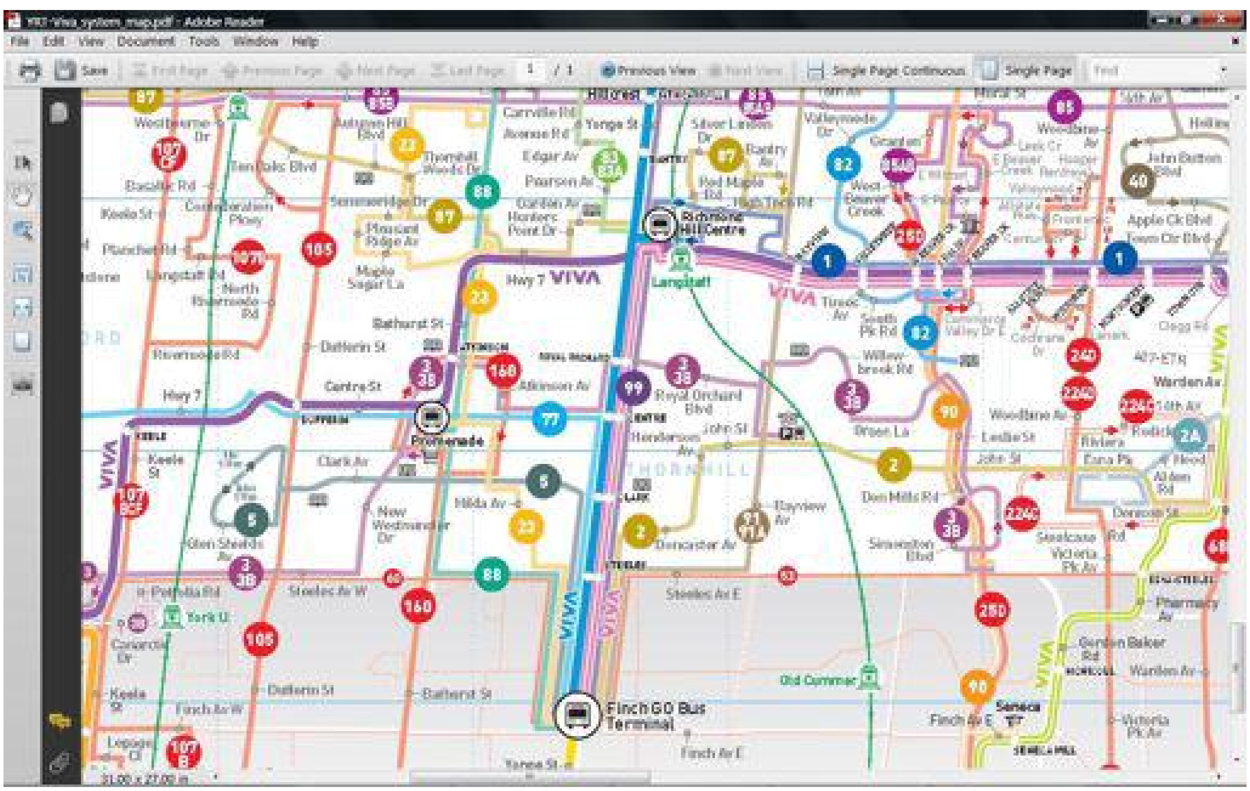

Figure 1 Partial York Transit System Service Map
(*Source*: York Region Transit)

To create the rapid transit network, YRT mapped out five Viva routes along 50 miles of arterial roadways. The five routes serve approximately sixty stops; eight are major transit centers connecting to rail service into Toronto or the outer suburbs of York. Station spacing ranges from 0.7 to 1.1 miles, complying with the design for a minimum distance requirement to reduce segment travel times. The streets with Viva lines in most locations are also served by local bus routes running YRT's conventional 40-foot coaches that serve other stops between the Viva stops.[21]

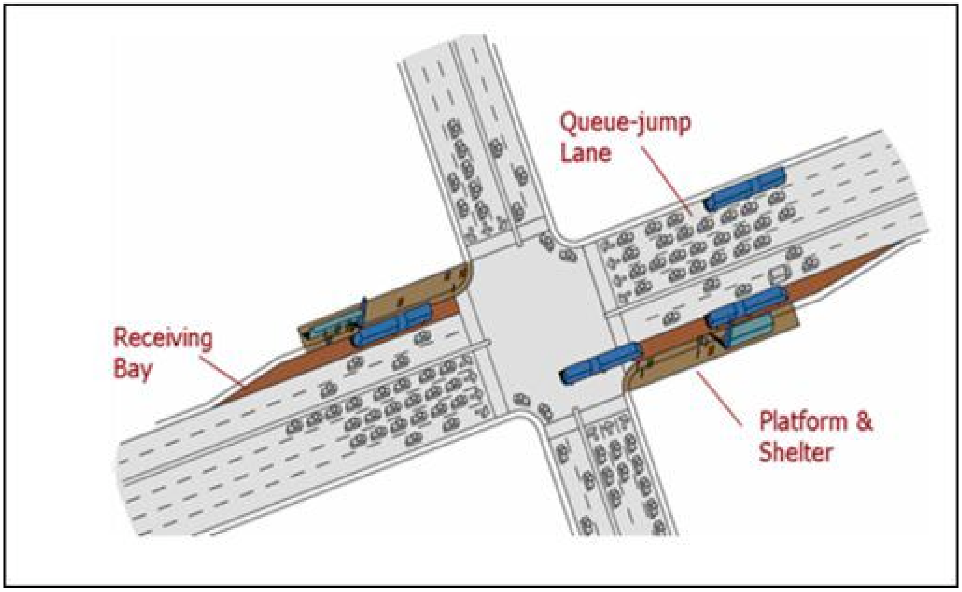

Figure 2 Queue Jump Lanes for Viva
(*Source*: York Region Transit)

YRT implemented two priority treatments to allow Viva buses to travel faster than local traffic. First, the buses are equipped with automatic vehicle location (AVL) equipment that communicates with a control center monitoring the buses. If buses are running late, the control center has the ability to extend a green light or shorten the red cycle. Second, YRT converted right-turn lanes at some intersections into bus-only queue jump lanes. The ITS and running way treatments cost approximately CA$36 million. According to the Transit Cooperative Research Board's *BRT Practitioners' Guide*, travel time improvements from these relatively modest investments vary widely depending on the level of congestion in the corridor, but are typically in the range of 8 percent to 12 percent for TSP treatments, with a 5 to 15 percent reduction in intersection delays due to queue jumps.[22]

Service Changes

YRT restructured some existing bus routes to feed the service by going from four to ten minute headways. These changes are a reflection of the corridor-based transit strategy, which seeks to create a few high-ridership corridors that can attract TOD. This is the strategy with trunk-oriented rail systems, where feeder buses deliver customers to rail stations, but it is not necessarily done on BRT systems. This strategy can lead to an increase in customer transfer rates and in some cases overall trip travel times rise for some customers. In fact, transfer rates increased significantly after the Viva was launched, although this may also be due to fare policies, as noted later.[23]

Stations and Fare Collection

The system is primarily served by on-street enhanced bus shelters, with major transfer points and termini equipped with more substantial stations. The on-street shelters are a single bus length only, with bus bays to accommodate boarding and alighting without impeding adjacent traffic. There is no level boarding, but, typically, passengers may board through all doors, since fare collection occurs before boarding. Viva uses proof-of-payment and random on-board inspections for fare enforcement. All stations have a ticket vending machine, electronic ticket validation, and a real-time display of when the next vehicle will arrive. The station and fare collection facilities are the second biggest infrastructure expense for the Viva, costing CA$37.38 million for the roughly 125 shelters and stations. Both features are key to the image of the Viva as a premium service; in addition, off-coach fare collection improves travel times by reducing station dwell times.[24]

Figure 3 Station Stop Shelters for Viva
(*Source*: York Region Transit)

YRT extended the time that a single-ride ticket is valid from 90 minutes to two hours, allowing riders to board as many times as desired during this period. Riders may also transfer free-of-charge from a regular YRT bus to the Viva, and YRT adopted a common fare medium across all services to ease transfers. These policies have contributed to the higher transfer rates.

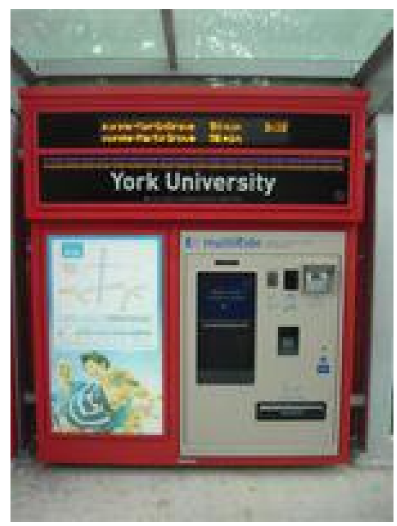

Figure 4 Viva Ticket Dispenser
(*Source*: York Region Transit)

Vehicles

At a total cost of CA$57 million, the vehicles are the biggest single expense for Phase I. YRT has 90 standard and articulated low-floor, clean diesel buses to serve the Viva. The vehicles are central to the Viva branding strategy that strives to promote Viva as a cool, fun, and environmentally friendly transportation option. The buses have the stylized exterior that is becoming more common in North American BRT systems. The interiors are spacious and attractive, with improved interior lighting and specialized fabrics. The vehicle livery is coordinated with the overall system brand, featuring the Viva logo and a distinct blue and white color scheme. Although there are mostly 40-ft. buses in the Viva fleet, the articulated 60-ft. vehicles tend to be the face of the system and are featured extensively in Viva advertising and marketing. Determining the differential impact that the stylish buses have on ridership is difficult, but YRT does report that some riders will let a regular bus pass by in order to ride the Viva bus.[25]

Branding and Marketing

YRT focused significant resources on branding and marketing, developing a comprehensive branding strategy for Viva to distinguish it as a premium service. The marketing campaign promotes the Viva as a fun, hip and environmentally-friendly transportation choice. The Viva name was developed following extensive marketing research, and the service has its own website and glossy promotional materials. This push for a distinctive identity even extends to the line level. The five lines are color-coded to distinguish them from conventional bus service, and the blue and white color scheme is used across all Viva elements.

Figure 5 Viva Articulated Bus
(*Source*: York Region Transit)

After the Viva began operating, the transit agency re-designed its logo to complement the Viva logo as well as creating a new joint YRT/ Viva logo. YRT wanted to ensure that customers understood the connection between YRT and Viva.

The total cost for the branding and marketing program was CA $4 million, a relatively small portion of the overall budget, which is detailed in Table 2 below.

Figure 6 (right) Viva's Low-Floor Boarding
(*Source*: York Region Transit)

Table 2 Breakdown of Viva Phase I Costs (Canadian Dollars)

Running ways	$18.2 million
Vehicles	$57.75 million
Facilities	$37.38 million
Intelligent Transportation Systems	$18.85 million
Branding & Marketing	$ 3.99 million
Other (planning, property acquisition, fare policy etc.)	$35.45 million
TOTAL	**$171.63 million**

Source: York Region Transit

The following chart provides a summary of the BRT elements listed in the standard FTA BRT reference document, "Characteristics of BRT," that have been included in York Transit District's Viva service.

Table 3 Comparison of BRT Elements from FTA Characteristics of BRT to Viva Elements

BRT Element	Viva: Phase I	Viva Phase II Additions
Running Way	On-street mixed-flow lanes. Limited bus-only lanes at intersections.	Dedicated median busway
Stations and Land Use	Enhanced on-street stations. Some off-street multi-modal transit centers. Regional strategy to encourage TOD around four Viva's four urban anchors.	Stations with enhanced passenger amenities. Continued TOD promotion.
Vehicles	High-capacity, low-floor stylized buses. No level boarding.	More articulated vehicles.
Service and Operation Plan	18 hours per day, 3–15 minute headways. Two peak-hour only lines.	
Fare Collection	Prior to boarding the coach	
ITS	TSP at all intersections to help late buses return to schedule	
Marketing and Branding	Strong branding and marketing program to differentiate Viva from other services and brand as premium rapid transit	

Source: Data assembled by Lisa Callaghan Jerram

Assessing the Viva

York District Transit has had great success increasing transit ridership in the Viva corridors, as the chart below indicates. The biggest surge occurred in the first full year of service, with total corridor ridership increasing by 56.57 % from 2005 to 2006.

Table 4 Ridership in the Corridors

Year	Conventional	Viva	Total (Year)
2004	5,300,035	Not in Service	5,300,035
2005	5,832,559	1,423,066	7,255,625
2006	4,225,187	7,134,982	11,360,169
2007	4,074,346	8,296,397	12,370,743

Source: York Region Transit

As the next chart shows, ridership continued to grow in 2007, but at a slower pace. However, the corridor continues to attract transit riders, with a 9 percent increase from 2006 to 2007. The ridership numbers also show that ridership on conventional bus service has decreased. Some riders, given a choice, opt to travel on the Viva instead of local buses. The relative weighting of impacts on ridership from shorter travel times, more direct routes, and consumer preference for the Viva's new vehicles and higher service quality has not been assessed.

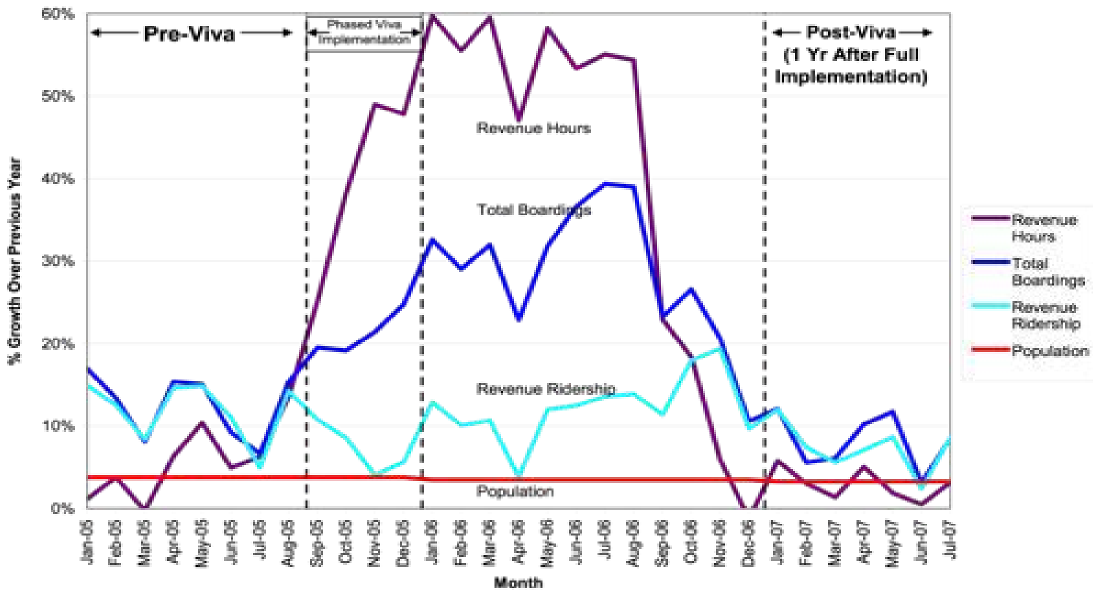

Figure 7 Viva Year-Over-Year Boarding Growth Rate
(*Source*: York Region Transit)

It is difficult to evaluate the travel time impacts of the Viva's priority treatments and service design improvements because the Viva corridors do not exactly map local bus routes. YRT has provided data on travel time changes relating to the Blue Line, the Viva's most heavily-used route. The data indicates modest improvements on travel time from before the Viva was launched.

Table 5 Travel Time changes for VIVA Blue Line: Finch to Bernard Stops

	Pre-BRT	Post-BRT	% Change
Maximum Peak Hour Running Time	44 min.	39 min.	-11.4
Uncongested End-to-End Running Time	35 min.	32 min.	-8.6

Source: York Region Transit, 2008

In addition, June 2008 data on end-to-end travel times for the five Viva lines indicate a high degree of variability in travel times in the afternoon. For example, the northbound Blue Line takes 57 to 60 minutes on weekday mornings and evenings, a three-minute range, but 64 to 74 minutes on weekday afternoons, a ten minute range. Similar variance exists with the other lines, showing that Viva is vulnerable to afternoon traffic congestion.

YRT also reports a significant increase in the transfer rates for customers—from 10 to 12 percent before the Viva to 25 to 30 percent as of late 2007. This change can also be seen in the ridership graphic, which shows a significantly higher increase in total boardings than in revenue boardings. According to the agency, this is due to both the local route restructurings and the fare policy change allowing unlimited transfers for up to two hours on a single ticket. The corridor-based transit model does require local bus routes to act as feeders to the central rapid transit corridors, thus reducing the proportion of single-seat rides.

Table 6 2007 York Transit Operating Costs, Per Mile

Viva	$3.91
YRT System	$4.86

Source: York Region Transit

In terms of implementation and operation, the incremental BRT strategy is producing good results. According to YRT, the Viva's per-mile operating costs are lower than the systemwide average.

As already noted, the Viva was implemented in an extremely short time frame for a major transit project—just three years from planning to service launch. This is largely the result of the strategic decision to run the service on public roads, thus eliminating the most difficult full BRT feature to implement, the dedicated running way. By contrast, YRT estimates that the full build in Phase II will take seven years to complete. This is a clear benefit of the incremental strategy, as transportation improvements are realized much more quickly. The new service is able to build transit ridership and attract transit-oriented development while the full build-out occurs.

In addition to the phased implementation, YRT also credits an innovative public-private transit partnership (PPP) scheme for speeding implementation and keeping costs down. The agency reports that such a scheme can be successful for BRT, but putting the PPP team together is harder than for rail projects. The partnership was launched early in the planning process, to involve contractors and operators throughout the process. The York PPP members jointly developed the environmental assessment, a network configuration master plan and a financing plan for the Viva. The public partners provided the primary funding source; set the service levels, fare policies and fares; and retain control over all assets and revenues. The private partners supply staff and other resources; provide a financing and procurement mechanism to reduce net costs and leverage public funds; and incur the risk on the budget and schedule. YRT has indicated that as long as there is a mechanism to protect the public interest, the PPP can provide significant cost and time benefits.[26]

Finally, while it is too early to tell how much impact the Viva will have on meeting the region's long-term land use goals, there is already one significant transit-oriented development project underway along the Viva. Downtown Markham is a 243-acre mixed-use community which the developer says will include 4,000 new condominiums and townhouses and more than 4.2 million square feet of office space. The heart of the project will be a promenade open only to pedestrians and the VIVA. The developer is working closely with YRT as the agency plans the dedicated transitway for the Viva. Plans call for re-routing a portion of the Viva service directly down the center of the pedestrian and transit promenade. The developer has secured the necessary right-of-way and is working with YRT to integrate the future stations with the development properties. The developer says the Viva is vital to the success of this new "urban-style" community in an otherwise suburban environment because it is important to offer an extensive, convenient and attractive transit network for prospective residents and commercial tenants.[27]

It is also worth noting that the Viva has been widely praised by the transit industry, the design and architecture organizations, and environmental groups. YRT reports that the Viva has 19 awards for advertising, brand and web design, infrastructure planning, and sustainable development, including the American Public Transportation Association's Innovation award. The project has also received favorable media attention. While this has no practical impact on the transit service, it does suggest that YRT's incremental BRT strategy has successfully improved the image and raised the profile of its transit system.

Future Plans

YRT is currently implementing Phase II of the Viva. As already discussed, Phase 2 involves the construction of dedicated median running ways, to be called "rapidways," along the Viva corridors. The rapidways will be designed to allow conversion to light rail if ridership increases sufficiently. YRT also envisions building more elaborate station structures to serve the rapidways. YRT has branded this effort "vivaNext." YRT is also coordinating the vivaNext design with a proposed Toronto subway extension that will travel along the Yonge Street corridor and connect with the Richmond transit center.

Since 2007, the agency has held open houses across the region to collect feedback on proposed alignments and conceptual design for vivaNext. The agency has also been working to secure the necessary federal and provincial funding, and construction is scheduled to begin in autumn 2009.

EMX GREEN LINE BRT: SINGLE CORRIDOR HEAVY BRT

The EmX Green Line in Eugene, Oregon is one of several BRT systems in the U.S. that was strongly influenced by Curitiba's iconic BRT. Launched in early 2007, the EmX operates in a four-mile corridor connecting Eugene and Springfield, the two largest cities in Oregon's Lane County. The EmX features all of the elements outlined in the FTA's *Characteristics of BRT* document: dedicated running ways, specialized vehicles with capability for off-board fare collection, new stations with near-level boarding, longer station spacing and short headways, signal priority, and strong branding.

The Green Line is the first segment of what is intended to be a network of rapid bus corridors serving Lane County. The Lane Transit District (LTD) plans call for building the network corridor-by-corridor over the next 20 years, replacing the existing bus service, based upon funding availability.[28] This represents the traditional approach to providing rapid transit service: heavy investment in high-level infrastructure improvements in a single corridor, with additional transit lines added over time as funding and demand permits. This approach derived more from the agency's long-term strategy for meeting increased transit demand and significantly improving the customer experience through implementation of premium rapid transit than from a pressing need to address near-term service or capacity issues. It also reflects the will of the public: BRT was proposed as a cost-effective alternative to the public's preferred mode, light rail. During the EmX design and planning process, LTD conducted extensive outreach and found that there was a strong preference for full implementation of BRT features to create a system that resembled light rail and could best compete with automobile travel.[29]

Figure 8 Planned Eugene EmX System Map
(*Source*: Lane Transit District)

The EmX does illustrate incremental BRT through its staggered deployment of some BRT features. Since opening, the system has been operating without any fares, as LTD had decided to wait to institute off-coach fare collection with the introduction of the second EmX Line in 2010. LTD subsequently decided to install ticket machines at stations in 2009; fare collection is set to begin in September 2009,[30] LTD is also planning to install real time passenger information displays at stations, but has been delayed due to difficulty finding an affordable product.[31] The running way design does reflect the inherent flexibility of BRT, combining dedicated transitways with arterial bus lane operations to comply with right-of-way restrictions along the route. Overall, however, the EmX is exemplary of the traditional single-corridor, high investment approach to transit and reflects the strengths and weaknesses of applying this model to BRT.[32]

Project History and Goals

The EmX is a major departure in transit service for the Lane Transit District, which until the EmX had exclusively operated traditional local bus services. LTD serves the roughly 220,000 metro area population of Eugene and Springfield, which are located about 60 miles from the Oregon coast. Lane County has a high transit ridership rate for a metropolitan area of its size, with over nine million annual boardings in 2006. LTD reports that ridership has doubled over the last 15 years.[33]

The decision to implement BRT was made in the mid-1990s in response to several events. First, in 1992 Oregon mandated that all large cities implement transportation plans that could reduce per capita vehicle miles traveled by 10 percent in 20 years. Around the same time, concurrent with the Regional Transportation Plan update, the LTD Board instructed the agency to create a 20-year vision for increasing transit capacity and improving service, especially travel times. The agency was concerned that traffic congestion was beginning to cause delays in bus service and would worsen over the long-term, seriously degrading bus service.

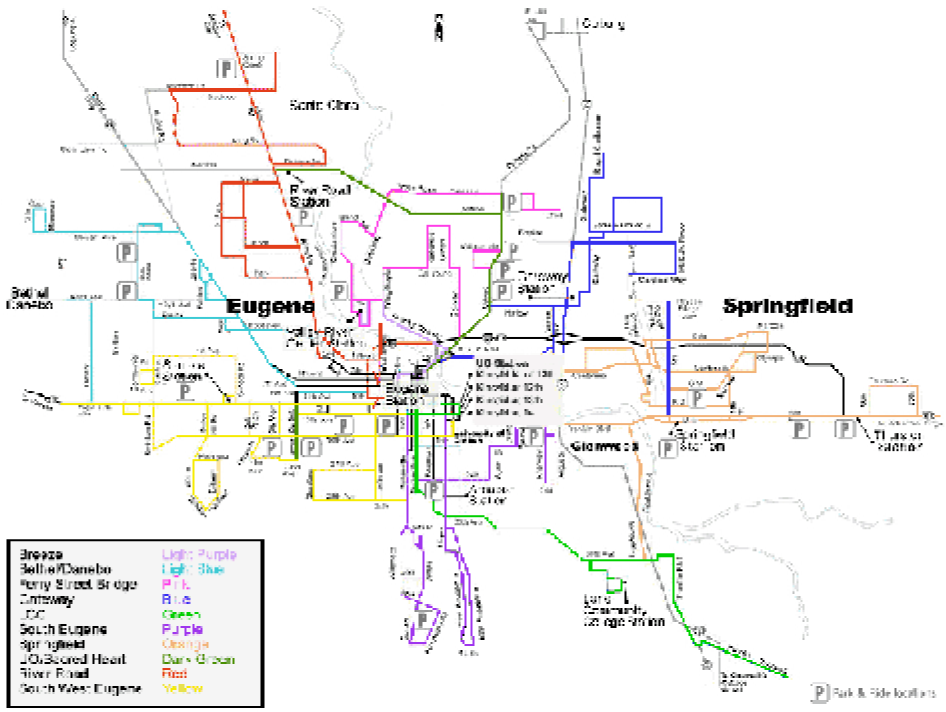

Figure 9 Lane County Transit Bus Network
(*Source*: Lane Transit District)

The agency first looked to light rail, which had recently been built in Portland, but quickly determined that the $30 to 50 million-per-mile investment could not be supported by Lane County's population base or funding availability.[34] The agency also concluded that minor enhancements to bus service would not provide sufficient improvement to satisfy the public, which had strongly favored light rail. Inspired by Curitiba's BRT, LTD decided that BRT could provide the light-rail experience desired by the community at an affordable cost. LTD also believed that BRT's flexibility would allow it to grow with the community. LTD adopted a strategy to upgrade all of its major bus corridors with BRT over 20 years. They mapped out a comprehensive system of BRT lines that would travel along existing routes, replacing local service. They called the system "the Emerald Express" or EmX, and decided to build the first EmX line in their highest ridership corridor, replacing the existing bus service along this corridor.

According to LTD, the primary goal of the EmX is to increase ridership by offering a competitive alternative to single occupancy car travel.[35] To achieve this, they expect the EmX to reduce travel time, increase reliability and offer convenient neighborhood connections. The agency also expects to reduce operating costs and support land use patterns. Finally, the EmX was designed to include non-transit enhancements such as landscaping, new sidewalks, and bike travel improvements.

This first EmX line was funded primarily through earmarks in the New Starts program, the main federal funding mechanism for major transit infrastructure projects. While New Starts makes building expensive projects viable, it also triggers an intensive federal oversight process, which can introduce significant delays into a project's implementation timeframe. In the case of the EmX, it took around a decade to plan and build the system, although other factors, such as the bus procurement, were responsible for significant delays. The New Starts program historically has been directed toward rail projects, and the funding process tends to reinforce the traditional single-corridor, high infrastructure investment approach to transit taken by Eugene.

The project's total costs were $24.6 million, or $6.15 million per mile. This is significantly lower than a comparable rail line would have cost; a light rail system laid down along the same right-of-way traveled by EmX would likely cost $30 to $50 million per mile, based on recent costs to build light rail in Sacramento, Portland, and Salt Lake City.[36] However, the EmX is more costly than a BRT project that relies on service upgrades like priority treatments and increased stop spacing, such as the Los Angeles Metro Rapid network, or even one like the York Ontario Viva that applies all BRT features excluding the dedicated running way. LTD's decision to implement the most expensive BRT option was influenced by the perceived public demand for the most "light rail-like" experience.

Building the EmX Green Line

In this section, the elements implemented on the EmX Green Line and the cost for each will be examined.

Running Way Priority and Routing

The EmX Green Line operates on a four-mile stretch between Eugene and Springfield. The line serves the two cities' downtown districts, the University of Oregon, and a major hospital. The Green Line replaced one of LTD's most popular bus routes, which served about 2,700 daily boardings. The Green Line has ten stops including the two termini; the prior bus service had 18. EmX stations are spaced an average of .44 miles apart.

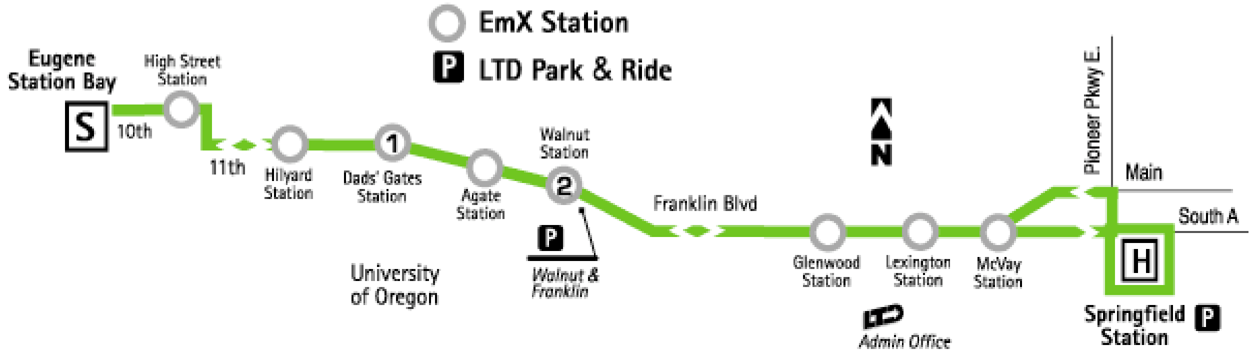

Figure 10 EmX Green Line Route
(*Source*: Lane Transit District)

A dedicated guideway was central to the agency's rationale for building the EmX, as LTD considered this critical to improving travel times and maintaining service reliability. However, the agency faced several problems in securing rights-of-way along this corridor. LTD was required to minimize disruption to auto traffic along the route, limiting their ability to remove parking or travel lanes. In addition, LTD could not relocate properties along the corridor, much of which is built out. As a result of these constraints, the agency has to make several compromises that have an impact on system capacity and vehicle travel time. First, about 60% of the corridor is a dedicated transitway in the road median, with signal priority at intersections. The remainder of the route is on curbside bus lanes with signal priority and queue jump lanes. The bus lanes are strictly enforced. More importantly in terms of system performance, portions of the median busway are single-tracked, with buses passing each other at two-lane stations. LTD uses block signaling at intersections and stations to control entry into the single bus lane. Portions of the busway are also extremely narrow: about ten feet wide at along the driving route and 9 to14 feet at stations. Finally, local environmental controls prevented LTD from removing trees along the running way, requiring planners to design the route around the trees. As a result, drivers must slow down when driving the articulated buses around the most narrow or curving portions of the running way.

Figure 11 EmX Guideway and Station
(*Source*: Lane Transit District)

Another impact of using both curbside and median lanes is the need for right and left side doors on the BRT vehicles. This and other advanced features like a hybrid drive train made the EmX vehicles very expensive. LTD justified the high price tag because these features would clearly identify the EmX as a premium service and differentiate it from regular buses.

Table 7 Costs for EmX Green Line

Design/Consulting Costs	$2,619,500
Property Acquisition Costs	$1,006,450
Construction Costs	$12,469,480
Miscellaneous Costs/Utilities	$517,170
Plan Review/Permits/Inspections	$545,610
Construction Support Costs	$1,463,840
Vehicles	$5,932,070
Total	**$24,554,120**

Source: *The EmX Franklin Corridor—BRT Project Evaluation,* FTA report, April 2009.

LTD does not provide a break-down of EmX capital costs by BRT element. However, as Table 7 shows, property acquisition, construction and utility costs related to the running way and the stations constituted the biggest project expense, at around $16 million for the entire project. The expense of a dedicated guideway may be justified when improved travel times are the primary performance goal, as with the EmX. Moreover, the LTD's decision to build a dedicated transitway appears to have been based as much on a desire to create a light rail type service as to improve travel time. However, this option has major trade-offs, as it limits the geographic reach of the transportation improvements and adds significant time and costs to the project's implementation.

Stations and Fare Collection

The Green Line's eight intermediate stops are served by enhanced stations of varying designs. They are not fully enclosed, but are attractive, distinctive, and comfortable. Some have waist-high screens separating the station from the running way to enhance passenger safety.[37] The median stations feature raised platforms that enable almost level boarding. EmX reduced costs by employing a low-tech guidance mechanism: yellow "plastic" strips along the platform edge to prevent vehicle damage if the drivers pull in too close. The system is not perfect, but does generally allow for near-level boarding.

LTD did not charge fares for the first two-and-a-half-years of service, opting to wait to implement an off-board, pre-paid fare collection until autumn 2009. This decision both saved money in the Green Line's budget and likely helped attract more riders. The agency reports that little revenue was lost because most riders hold a system wide transit pass or have paid the feeder bus fare.

Level boarding and pre-paid fare collection are important in reducing end-to-end travel times. Along with the multi-door vehicle boarding, these can significantly reduce station dwell times. Substantial stations also contribute to the sense that the system is a "premium" service and make it easier for passengers to identify the station stops along the curbside lanes where the station competes with existing sidewalk infrastructure.

The stations are not yet equipped with real-time passenger information because LTD has been unable to find a vendor that will suit their needs and budget. This can be an important

Figure 12 EmX Median Station Illustrating Left Side Bus Doors
(*Source*: Lane Transit District)

factor in travel time perceptions: according to the CBRT, research indicates that passengers believe their wait time to be less than it is when they have real-time information available.

Vehicles

The EmX uses a fleet of six 63-ft articulated low floor buses with a modern, sleek silhouette and a hybrid-electric drive. They have a green and silver livery with the EmX logo. The buses seat 44 (the dual-side doors and bicycle racks limit seating capacity) and provide standing room for 50 to 60 more riders.

Although the stations have near-level boarding, passengers in wheelchairs must enter the buses through the middle doors, where a ramp can be deployed to bridge the gap between the bus and the curb.

The vehicles were the project's second biggest capital cost and are a key branding element.

Finding the right buses posed a major challenge and was a significant factor in the project's lengthy development time. When LTD began planning the EmX, no North American bus company was making the kind of stylized vehicle that LTD wanted. After exploring European bus options, LTD decided to partner on a procurement with Cleveland's transit agency, which also wanted articulated stylized buses with dual side doors and hybrid propulsion for its planned BRT. New Flyer was the chosen vendor. The two agencies and New Flyer worked together to develop the vehicles, which cost $960,000 apiece, a reflection of the buses' novelty at the time. Now, several North American manufacturers are promoting BRT-stylized bus models, giving agencies greater choice at lower cost.

Figure 13 EmX Bus in Dedicated Curb Lane
(*Source*: Lane Transit District)

The buses are considered critical by LTD to the EmX identity as a premium rapid transit service. The modern look, the distinctive livery, the multi-door boarding and the hybrid drive system all help to distinguish the vehicle from the rest of LTD's fleet and present a high-quality image. They are also critical to maximizing capacity on the service.

Service Changes

As already noted, the Green line replaces one of LTD's most popular local bus lines in this corridor. It was not necessary to alter other local lines to feed the route. The line connects the transit hubs for both Eugene and Springfield, and several existing lines cross its path. The EmX operates with 10-minute headways on weekdays, while the former local service ran every 15 to 30 minutes. The EmX also operates on a headway basis and seeks to minimize travel time with strict dwell time limits. Although the EmX has signal priority at intersections, its travel times are affected by the need to yield right of way to left-turning motorists or pedestrians activating crosswalk signals.[38]

Branding and Marketing

Image was an important consideration throughout the system development. LTD saw the investment in high-cost elements such as specialized vehicles and stations with level boarding as not only serving performance outcomes, but also as creating a premium image that can attract riders out of their cars.

LTD also decided to promote the image of a “green” service, in keeping with the area’s environmentally conscious community. This image is reinforced throughout the system—the green livery, the hybrid drive system, native landscaping along the transitway, and one unusual feature: a grass strip down the center of the guideways. The grass not only looks attractive, but also helps absorb fluid leaks from the buses. LTD also commissioned construction of a new bus station designed to meet national “green building” standards for the Green Line’s eastern terminus in Springfield.

Assessing the EmX

Since opening in January 2007, the EmX has succeeded in meeting LTD’s primary goal of increased ridership. The previous local bus service had around 2,700 average weekday boardings. Daily corridor ridership increased by 100 percent in the first 17 months since the service began, reaching 5,400 weekday boardings as of April 2008. As the chart below shows, corridor ridership has surpassed the 20-year projection. By comparison, LTD’s total bus ridership increased by 4.8 percent from 2006 to 2007.

Based on an early ridership survey, the agency estimates that as many as 25 percent of EmX users are new riders, with 16 percent of riders previously traveling by car. The agency has also reported that they had to add buses on some of their local routes to meet increased passenger demand. Some of this increase may be because the EmX is free, although LTD reports that most riders own system wide passes or have paid the fare on the local feeder bus.

Table 8 Comparison of BRT Elements from FTA *Characteristics of BRT* to EmX Elements

BRT Element	EmX Green Line	Planned Additions
Running Way	Dedicated median running way for 60% Curbside bus lanes for 40%	
Stations and Land Use	Enhanced stations with near-level boarding. Two transit centers, with joint development at one.	
Vehicles	High-capacity, low-floor stylized hybrid buses. Multi-door boarding on both sides.	
Service and Operation Plan	10 minute headways. All-stop service only. Longer station spacing than local service.	
Fare Collection	None for 2.5 years.	Off-coach, pre-paid fare collection as of Sept. 09 Station ticket machines
ITS	TSP at all intersections, queue jump	Real-Time Passenger information.
Marketing and Branding	Strong branding and marketing program to identify EmX as premium rapid transit.	

Source: Data assembled by Lisa Callaghan Jerram

The Green Line's success has raised concerns about system capacity. The agency reports that ridership now reaches 500 passengers an hour at peak times.[39] The buses have a total standing capacity of 100 passengers. At current 10-minute headways, the system can accommodate 540 passengers an hour.[40] Unfortunately, the single-lane portions of the transitway limit the number of buses that can operate at one time. Currently, LTD planners think they can achieve no better than seven-minute headways. Over time, this issue could limit the system's ability to meet rising ridership demand.[41]

Compared to the former Route 11 bus, the EmX has reduced the average end-to-end travel time in the corridor by one minute from 16 minutes to 15 minutes. Most of the time saving has come from transit signal priority. Reliability of running time has been improved notably, as measured by the standard deviation from the observed mean travel time: 116 seconds for Route 11 compared to 79 for the EmX. [42]

LTD reports that operating costs per rider are intended to be lower for the EmX than for regular bus service.

Shortly after opening, the EmX experienced several collisions between the buses and other vehicles at guideway intersections. This has been a problem for other BRTs with at-grade intersections, such as the Los Angeles Orange Line. However, the accident rate declined once area drivers became accustomed to the busway.

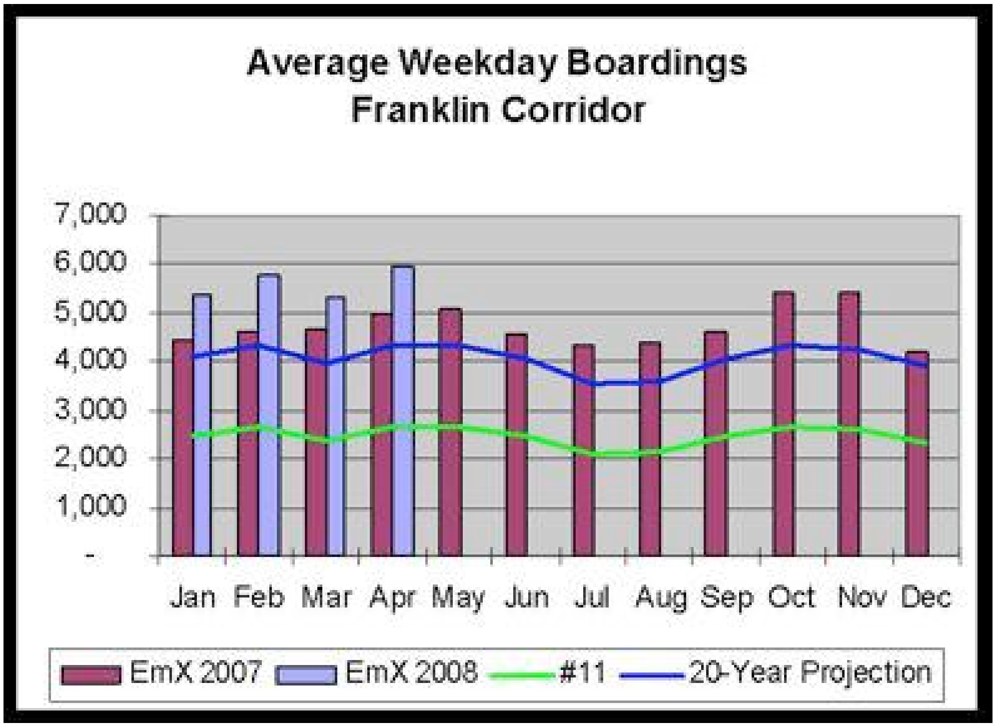

Figure 14 Ridership Growth Following EmX Service Initiation
(*Source*: Lane Transit District)

Interestingly, some customers do not like the new emphasis on speed and efficiency. Early news reports quoted passengers who complained that the EmX drivers are not allowed to wait for passengers approaching the bus station since they must keep to a strict timetable, and are discouraged from talking with passengers. LTD notes that some passengers prefer the more "laid-back" style of the regular bus service.

Overall, the EmX has performed well, increasing ridership and improving travel times. The agency's approach has made the EmX a model for other US cities interested in using high-level BRT to provide a "light rail-like" experience in a small city that cannot justify rail investment. This approach did result in an extremely long implementation period, likely caused by several factors. First, building an on-street transitway requires extensive community outreach to secure buy-in, as well as a long period of construction. Second, LTD needed to procure an entirely new type of transit vehicle in order to have a coach with the attributes the agency desired. It is now common for American bus companies to offer BRT-styled vehicles, so this is less a problem for agencies today. Finally, the use of the New Starts funding mechanism entails a lengthy federal oversight process.

Finally, while it is too early to determine whether the EmX is helping the region meet its land use goals, there has been some promising activity. For example, proposals for mixed use development around the Walnut Station are being considered. This area has been designated in regional plans for mixed-use development due to its location on the EmX.

Figure 15 Wheelchair Customer Using Ramp to Board EmX
(*Source*: Lane Transit District)

This may be a benefit of a system with major infrastructure investments, as early research on BRT's land development impact indicates that local planners and developers respond favorably when there is clear evidence of a long-term commitment to transit in a particular corridor, demonstrated especially by major infrastructure improvements.[43]

Future Plans

Construction is underway as of 2009 for the second EmX corridor, the Pioneer Parkway line. Planned to open in 2010, this will be a 7.8 mile route running north from the Springfield station. The route will take advantage of new roadways and an abandoned rail right-of-way to build the dedicated busway. The estimated cost is $41 million or $5.2 million per mile, lower than the Green Line. LTD has been awarded funding for the project under the new "Small Starts" program, which Congress carved out from the broader New Starts program to support low-cost projects that operate substantially on a fixed guideway or are corridor-based bus projects. This project will take significantly less time to implement than the Green Line. Planning is underway for the third proposed EmX line.

LOS ANGELES COUNTY: METRO RAPID LIGHT BRT AND ORANGE LINE HEAVY BRT

Los Angeles offers a chance to compare BRT strategies at opposite ends of the spectrum. The Los Angeles Metro Rapid program exemplifies an incremental BRT approach that builds on existing, conventional arterial bus service, applying relatively easy and inexpensive upgrades while retaining the option to deploy higher order elements later. The program relies upon transit signal priority and longer station spacing to improve travel times in mixed traffic. By using existing roadways, on-board fare collection and fleet vehicles with a distinct livery, the Los Angeles Metropolitan Transportation Authority (Metro) has kept program costs quite low: Metro estimates that it costs $50,000 per station and $100,000 per mile for the ITS treatments. This low investment level has enabled the agency to implement these features on almost 450 miles of BRT routes.

By contrast, with the Orange Line, Metro made a significant investment in deploying a full-featured BRT in a single 14-mile corridor in the San Fernando Valley. The decision was driven in part by the availability of right-of-way in the corridor and a long-standing commitment to build a premium rapid transit system to serve the Valley. This heavy BRT strategy resulted in high investments for all BRT components, including a dedicated running way; substantial stations; high-capacity vehicles; off-coach fare collection; and landscaping, bike and pedestrian paths and park-and-ride lots. Total cost of the Orange Line was around $350 million, or $25 million per mile, higher than the Metro Rapid, but much lower than other Los Angeles rail projects like the Gold Line, a 13-mile light rail that cost $66 million per mile.

The concept for each system was inspired by a 1998 site visit by transit agency officials and local policymakers to the BRT system in Curitiba, Brazil. However, the design approach chosen for each investment was driven by the differing performance and cost goals, alignment availability and political considerations. Each has proven successful in increasing ridership and decreasing travel times. Both also were launched in a relatively short timeframe, with Metro Rapid service especially quick to implement. These two LA systems demonstrate that there is no “one size fits all” approach to designing an effective transit service. [44]

Projects’ History and Goals

As of 2007, Los Angeles Metro was the third largest transit agency in the U.S. with approximately 495 million annual boardings. The agency serves a 1,688 square mile area with a population of 11.8 million as of the 2000 census. Metro operates heavy rail subway, light rail, and bus service, in addition to other specialty transit services such as vanpools. The bus system is the service workhorse, with almost 413 million boardings in 2007, compared to 40.9 million on the Red Line subway and 41.35 million on the three light rail lines.

Table 9 Metro Rapid Incremental Strategy

1. Frequent Service 2. Bus Signal Priority 3. Headway-based Schedules 4. Simple Route Layout 5. Less Frequent Stops 6. Integrated with Local Bus Service 7. Level Boarding and Alighting 8. Color-coded Buses and Stations	Phase I
9. High Capacity Buses 10. Exclusive Lanes 11. Off-vehicle Fare Payment 12. Feeder Network	Phase II

Source: Los Angeles CountyMetro

The Metro Rapid program was instituted primarily to address concerns over bus service quality. The agency goals were to improve operating speeds and reduce bus bunching, passenger waiting times and passenger standing loads. Following the 1998 trip to Curitiba, the agency developed a strategy to improve bus service using BRT elements. Based on the Curitiba model, Metro developed a list of 12 key BRT attributes (Table 9) and crafted an incremental strategy to deploy these features. Under this strategy, Metro would conduct an initial demonstration along two high-ridership arterials. This pilot program would implement eight BRT features that could be deployed on an expedited build schedule. Metro’s stated goals for the program were to reduce passenger travel times, increase ridership, attract new transit riders, increase service reliability, improve fleet and facility appearance, improve service effectiveness, and build positive relations with communities.

If the demonstration proved successful, Metro would expand the pilot program to add more bus lines with the same BRT features, and begin planning for Phase II, which would see the addition of the other four, more costly BRT features.

The agency adopted the Metro Rapid Demonstration Program in March 1999, and the first two lines opened just 15 months later in the summer of 2000. The pilot project proved successful in reducing travel time and attracting new riders, so in 2002, Metro began implementing the same elements—tweaked slightly based on findings from the initial demonstration—on major bus corridors throughout LA.
.
Launched in October 2005, the Orange Line BRT evolved in a very different context. In this case, bus rapid transit was seen as an opportunity to provide a premium, high-capacity rapid transit service in the under-served San Fernando Valley north of downtown Los Angeles. The Orange Line corridor lies in an abandoned railroad right-of-way purchased by Los Angeles Metro in the early 1990s. The corridor is mainly a residential zone with little commercial activity except at the Warner Center, a large mall and office complex at the western end of the Orange Line, and the North Hollywood neighborhood at the eastern end of the corridor. Until the Orange Line was built, the Valley was served exclusively by local bus routes, with the Red Line subway terminating in North Hollywood.

Table 10 Orange Line Costs

Running Way	$180 million
Stations (including park & ride lots)	$72 million
28 vehicle initial fleet	$16 million
ITS	$10 million
Fare Collection	$6 million
Other	$66 million
Total	$350 million

Source: Los Angeles County Metro

The transit agency originally purchased the right-of-way to build the community's first rail line, which would connect to the Red Line subway, providing a rapid transit ride from the Valley into downtown LA. Political opposition to rail funding prevented the agency from pursuing either heavy or light rail. BRT became the solution to this problem, allowing the agency to build the type of service that it wanted for the corridor and at lower cost than a light rail or subway line.

Agency and local officials appear to have been committed to a high-investment full BRT from the beginning of the planning process, in part because of the existing interest in utilizing this rail corridor as a dedicated transitway. There was opposition from a local activist group that challenged the transit agency's selection of full BRT, arguing that Metro Rapid would be a better choice for the San Fernando Valley. The group, Citizens Organized for Smart Transit (COST), disputed the projected travel time savings used to justify the project. COST predicted that actual time savings would be much lower because the buses, while separated from traffic, would still have to cross traffic at the busway's multiple at-grade intersections. COST asserted that Metro could achieve comparable travel time savings at much lower cost by implementing additional Metro Rapid service in the Valley.

Ultimately, Metro prevailed and built the full BRT option. The agency concluded that the proposed full BRT with a dedicated busway would offer several benefits:

- End-to-end travel time that would be in the range of 28.8 to 40 minutes, faster than proposed Metro Rapid alternatives;
- More consistent travel time savings;
- Ability to attract more riders and more new transit customers; and
- Better support for local land use policies by placing high-capacity service near activity centers targeted by the city for TOD.

Building the Metro Rapid and Orange Line BRTs

In this section, the researchers examine the elements implemented for both the Orange Line and Metro Rapid, and the cost for each system.

Running Way Priority and Routing

The 14-mile Orange Line busway runs along an east-west axis through the San Fernando Valley and roughly parallel to US 101, a congested Los Angeles highway. The eastern terminus is the North Hollywood Station, which provides a connection to the Red Line subway. However, there is no direct access; riders must cross Lankershim Boulevard between the Orange Line and the underground rail station. The Orange Line schedule is timed to optimize transfers. The western terminus is the Warner Center, a large shopping, residential, and office complex surrounded by parking lots. For the last half-mile of its route, the Orange Line leaves the busway and travels in mixed-traffic arterial streets to the Warner Center. Several bus lines stop here, making it an important transit hub.

The Orange Line is not grade separated, and it crosses approximately 36 intersections and has five mid-block pedestrian crossings. The decision to operate at-grade without crossing gates or other barriers has had safety and performance implications as will be described later. The Orange Line intersections have synchronized signals that give the buses up to 10% more signal time. The busway does not offer full signal priority as planners determined this would cause significant delays to auto traffic crossing the busway.[45]

The 14 stations are spaced roughly one mile apart. Only the Orange Line operates on the busway; no other transit or high-occupancy vehicles are permitted to use the busway. Because this was an abandoned rail line, there was no local service on the corridor before the BRT. Orange Line stations connect to more than 20 local and Metro Rapid bus lines, as well as the Red Line subway at North Hollywood.

The dedicated busway accounts for a little over half the Orange Line's $350 million budget. These costs do not include the original purchase price for the right-of-way. The 20-mile railway alignment was purchased for $122 million in the early 1990s, and the Orange Line utilizes roughly 13.5 miles of it.[46]

Figure 16 Orange Line Station
(*Source*: Los Angeles County Metro)

As of mid-2009, the Metro Rapid system has a total of 26 lines. The network runs in 450 miles of mixed-traffic arterials along some of the city's busiest transit corridors. The service is overlaid onto local routes, using increased stop spacing and transit signal priority (TSP) to reduce travel times. Metro Rapid station spacing averages 0.7 miles, with some lines even higher, in contrast to local bus spacing of 0.2 and limited stop service spacing of 0.3 miles.

The decision to implement TSP was made after agency surveys found that bus riders' biggest complaint was that service was too slow and unreliable. A study conducted by the Los Angeles DOT indicated Metro buses were stopped 50 percent of the time they were in service. As a result, Metro determined it could quickly and cost effectively improve travel times and reliability by reducing the length of time the buses were stopped at stations and signalized intersections. The system grants signal priority to buses behind the scheduled headway by extending the green light up to ten seconds or activating a green light ten seconds early. This is intended not only to reduce time stuck at intersections but also to reduce bus bunching.[47]

Figure 17 Orange Line Station Shelter
(*Source*: Los Angeles County Metro)

The ITS system also feeds into the real-time passenger information system described below. ITS is one of Metro Rapid's two major cost elements. It is installed at around 1,000 intersections in the Metro Rapid network at a cost of just $100,000 per mile.

Stations and Fare Policy

Metro constructed enhanced stations to serve the Orange Line busway. They feature an open design with protective shelter, seating, lighting and other passenger amenities. Stations feature real-time passenger information displays and are clearly posted with the station name. They are decorated with public art and landscaping, and are kept clean and well-maintained.

In an effort to limit dwell times, Metro built eight-inch station platforms—two inches higher than standard sidewalks—to minimize the step that passengers take up into the buses. The Orange Line also has off-coach fare collection so passengers can board through multiple doors. Stations have automated fare machines, and fares are enforced through a proof-of-payment system based on random inspection.

Figure 18 Metro Rapid Station
(*Source*: Los Angeles County Metro)

Some stations have multiple canopies to allow more than one bus to board and alight at one time; some, but not all, have passing lanes. The Orange Line also features seven park-and-ride lots with over 4,000 free spaces to attract transit customers who wish to access the system stops via automobile. In all, the stations and parking lots constitute the second largest cost, at $72 million.

Because Metro Rapid stations are located on sidewalks in urbanized corridors, they are designed to minimize the station footprint. Most of the over 600 Metro Rapid stations are simple sidewalk bus stops, designated by distinct signage and service maps; a few major stations have real-time passenger information. About one-fifth of the stops are served by enhanced stations, with a translucent canopy overhang and rail bar; these feature the same passenger amenities as well as seating and lighting. Metro uses conventional on-board fare collection. Metro Rapid stops are not co-located with local stops and are typically placed directly after the intersections, in contrast to local stops, which are stationed before intersections. Facilities are Metro Rapid's second major cost item; the agency estimates that it spends about $50,000 per station.

Figure 19 Metro Rapid Station Loading Passengers
(*Source*: Los Angeles County Metro)

Vehicles

Vehicles are an important element for both systems. Metro ordered 60-ft. specialty vehicles for the Orange Line fleet. The agency refers to them as "Metroliners," and the vehicle design and livery are intended to resemble rail vehicles. The buses have the sleek, curving lines that are becoming more common in contemporary bus design; they are silver, to match Metro's rail cars, and have wheel skirts to enhance the rail-like appearance. With the stations' raised platforms, the low-floor buses achieve close to level boarding, but passengers must still step up into the buses. The buses have three right-side doors for

Figure 20 Orange Line Articulated Bus
(*Source*: Los Angeles County Metro)

boarding and alighting. Total cost of the 28-bus fleet was $16 million.

Metro Rapid uses conventional 40-ft buses, as well as some 45-ft and 60-ft buses on high demand routes. While these were not a special procurement, Metro does primarily use recent model year buses, which have a sleeker look than older models. The buses have a distinctive red and silver livery to distinguish them from local buses. Metro Rapid materials frequently note “level boarding” as one of the BRT attributes implemented in Phase I. In reality, Metro has simply deployed low-floor buses; since the stations are sidewalk-based; this means passenger must still take a step up into the bus.

Table 11 Metro Rapid Costs

Stations	$50,000 per station
ITS	$100,000 per mile
Projected Total For Complete Network (as of April 2008)	$110 million
Vehicles	$350,000 for 40-ft. CNG bus $630,000 for 60-ft. CNG bus

Source: Los Angeles County Metro[48]

Metro does not include vehicle costs in its Metro Rapid budget, since the vehicles are acquired through the agency’s overall fleet procurement process, rather than as a specialty fleet like the Orange Line buses. The bus prices are typical for recent model year buses powered by compressed natural gas.

Branding and Marketing

Branding and marketing are also key components of Metro’s two BRT systems. Each has a unifying design and color scheme that serves both to help customers distinguish the BRT from other bus lines and promote it as a premium service. The Orange Line branding scheme, as already evinced in the discussion of the livery, is intended to link it to the rail system by giving it a color name, like rail lines, instead of a number; integrating it into the rail network map; and selecting a vehicle design that resembles rail cars.

Metro Rapid lines are identified by route numbers, as are other bus lines. However, the buses and stations share a color and design look to ensure that customers can identify the service easily. The Metro website also has a separate section outlining the Metro Rapid routes and describing the program.

Service Design

The Orange Line runs at four-minute headways during peak hours. Metro increased service from the original five-minute peak hour headways in response to high ridership demand. The service operates 22 hours per day, seven days a week, with evening and weekday headways reduced to 15 to 20 minutes. Service is all-stop only, as there are no passing lanes along the busway and only some stations with passing capability. Schedules are coordinated with the Red Line subway to ease transfers from the North Hollywood terminus; however, it is an inconvenient connection since passengers must cross the street to enter the subway station. Orange Line stations also connect to approximately 20 local and Metro Rapid bus lines. Drivers are allowed to minimize trip times by skipping stops if there are no passengers requesting the stop.

Figure 21 Orange Line Station Sign
(*Source*: Los Angeles County Metro)

Metro Rapid runs on a headway-based schedule, meaning buses do not idle at stops when ahead of schedule but instead travel the route as fast as traffic and signals will allow. Schedules vary for each line, but most have peak hour headways between five and fifteen minutes. A few of the high-demand lines have service frequencies of two to five minutes. Off-peak headways are between 10 to 20 minutes for most lines. The service is all-stop, since the routes have already been designed to maximize efficiency by serving each corridor's highest-demand stops. There are some peak-service only lines. As the agency introduces new Metro Rapid lines, it will also reconfigure local routes if needed to maximize overall system efficiency.

Table 12 provides an overview of the BRT elements found on the two kinds of BRT operating in Los Angeles County.

Table 12 Comparison of BRT Elements from FTA *Characteristics of BRT* to Metro Rapid and Orange Line

BRT Element	Orange Line	Metro Rapid Phase I	Metro Rapid Phase II
Running Way	Dedicated at-grade running way	On-street mixed traffic lanes	Peak period exclusive lanes on Wilshire Blvd.
Stations	Enhanced stations with raised platforms.	Basic stops and shelters with Rapid branding.	
Vehicles	High-capacity, low-floor stylized buses. Multi-door right-side boarding.	40-ft, 45-ft and 60-ft low-floor fleet vehicles with Metro Rapid livery.	More high-capacity vehicles.
Service and Operation Plan	4-minute headways at peak; 15–20 at off-peak. Some headway-based operation. All-stop service only. One-mile station spacing.	Varies for each line. From 2–15 minutes peak, 10–20 minutes off-peak.. Headway-based schedules.	
Fare Collection	Off-coach, proof-of-payment	On-coach.	Plans for off-coach have been shelved due to insufficient room at stops for ticket vending machines.
ITS	Synchronized signals at all intersections Real-time passenger info	Transit signal priority at all intersections. Real-time passenger info	
Marketing and Branding	Strong branding and marketing to identify Orange Line as premium rapid transit and as “rail-like”	Branding and marketing to identify stations and vehicles and promote premium service image.	

Source: Data assembled by Lisa Callaghan Jerram

Assessing the Orange Line and Metro Rapid

This section will review how Metro Rapid has performed since the first lines were launched in 2000; this study will report performance metrics averaged across the total system, not disaggregated by line. This section also reviews the performance of the Orange Line since it opened in late 2005. Each system has shown it can attract riders and improve service. Each also was created to serve different goals, which will be taken into account when judging performance, and each has different limitations or challenges relating to the BRT strategy selected.

Ridership: Los Angeles implemented BRT primarily to improve service quality for existing transit customers, with increased ridership as a secondary goal. Nevertheless, both BRTs have indeed increased ridership in their respective corridors. In 2007, Metro reported the changes in ridership for Metro Rapid corridors opened since 2000. Total corridor ridership, for both the Metro Rapid lines and the local lines, went from 388,400 average weekday boardings to 464,400, a 19.6 percent increase. Orange Line ridership figures indicate an even bigger increase. Prior to the Orange Line service's launch in autumn 2005, the corridor averaged 41,580 average weekday transit boardings; as of 2007, average weekday boarding reached 62,597, a 51 percent increase. The Orange Line itself has averaged over 26,000 weekday boardings in 2008, surpassing the agency's stated ridership goal for 2020 in just two years. By comparison, total system bus ridership increased by 9.4 percent from 2005 to 2007 (note that this figure includes the Orange Line and Metro Rapid ridership); heavy rail ridership increased by 12.7 percent; and light rail ridership increased by 8.9 percent.[49]

As of April 2009, the four L.A. Metro rail lines are experiencing 293,000 daily weekday boardings, while the 26 Metro Rapid bus lines have 228, 000 and the Orange Line has 21,000.[50]

Neither system has undergone a major ridership evaluation that would indicate how many new transit customers they are attracting. There were some very early evaluations that found good results. A September 2000 rider survey on the two pilot Metro Rapid corridors found that one-third of the passengers said they were new to transit. An Orange Line rider survey conducted in January 2006, just three months after the BRT opened, found that 17 percent of the riders were new to Metro, and one-third had a car available for the surveyed trip.

Travel Times, Speed and Reliability: Reducing travel time in the Orange Line corridor was presented as a key rationale for investing in full BRT instead of lower level bus service improvements. Metro originally projected that end-to-end travel times would be between 28.8 and 40 minutes. As of 2008, actual travel times have averaged around 42 minutes at peak hours, a 16 percent improvement over the pre-BRT time of 50 minutes, but short of the agency's goal. Non-peak travel times improved from 45 minutes to 37 minutes, an 18 percent improvement. Note that the differential between peak and non-peak performance did not change with dedicated busway, with non-peak travel five minutes faster both before and after.

The primary reason for not meeting travel time projections relates to safety issues when buses cross the at-grade intersections. Shortly after the Orange Line opened, it experienced a number of accidents from vehicles or pedestrians crossing the transitway intersections illegally. Metro addressed this issue by installing more signs and signals to increase awareness of the busway, as well as launching an educational campaign on busway safety. Most significantly, Metro has reduced bus speeds through intersections from 25 mph to 10 mph. Since the busway crosses more than 20 signalized intersections, this has a significant travel time impact. Even though safety rates have improved dramatically since the busway opened in 2005, the agency has not announced any plans to increase the permitted intersection speed, thus limiting the Orange Line's ability to meet its original travel time targets.

Metro has not implemented true signalized priority along the Orange Line busway. Signals are synchronized in an effort to give buses a "constant green" along the running way, but in reality, buses often stop at red lights. As discussed in the Project History section, one reason for not deploying TSP was traffic engineers' concern that, because of the short headways, there would be a significant negative impact on north-south traffic crossing the busway.[51]

As of 2008, reported travel time improvements in Metro Rapid corridors range from 21 percent to 37 percent over the local bus service. Overall, Metro reports that Metro Rapid travel times are 25 percent better than the local service. This is a significant improvement given that Metro Rapid operates in mixed traffic. A 2002 evaluation on the two pilot corridors attempted to determine which of the deployed BRT attributes contributed most to travel time savings on the two lines. The evaluation found that the signal priority accounted for approximately one-third of the improvement, while the other system features—fewer stops, far-side stations, low-floor buses, headway-based schedules, and active service management by field supervisors and a control center—accounted for the remaining two-thirds.[52]

While the higher investment in a dedicated busway has not resulted in better travel time improvements, the Orange Line does appear to offer greater travel time consistency than Metro Rapid. An April 2006 presentation by a Metro representative compared travel times for the Orange Line and the Metro Rapid Ventura Line, which runs roughly parallel and is two miles longer.

Table 13 End-to-End Travel Time and Average Speed Comparison Between the Ventura Metro Rapid Line and the Orange Line

	Ventura Metro Rapid (16.4 miles)		Metro Orange Line (14 miles)	
	Total Time	Average Speed	Total Time	Average Speed
a.m. Westbound	44 minutes	22.4 mph	50 minutes	16.8 mph
a.m. Eastbound	45 minutes	21.9 mph	41 minutes	20.5 mph
p.m. Westbound	50 minutes	19.7 mph	51 minutes	16.5 mph
p.m. Eastbound	59 minutes	16.7 mph	41 minutes	20.5 mph

Source: Rex Gephart, Metro Rapid program manager, presentation dated April 2006

This chart shows that the Ventura Metro Rapid moves along its route at higher speeds than the Orange line except for eastbound afternoons. However, Metro Rapid shows higher variability in travel time in both directions depending on the time of day; average speed for the Orange Line is almost constant for each direction, while it varies significantly for the Metro Rapid service. This indicates that the dedicated busway reduces customer uncertainty about travel times on any given day and time.

Transfers: The Orange Line was designed in part to feed customers from the San Fernando Valley into downtown Los Angeles, via the Red Line Subway. The January 2006 rider survey confirmed that a large percentage of riders used the BRT as a commuter feeder to the subway, with 73 percent of morning passengers and 57 percent of midday passengers alighting at North Hollywood. The survey also found that almost 50 percent of all surveyed riders arrived via another transit mode, while 57 percent said they would connect to transit after leaving the Orange Line. This indicates that the Orange Line serves primarily as a feeder to other transit, rather than as a single-seat transit trip along the corridor.

Table 14 Comparison of Operating Efficiencies

Operating Cost Efficiencies	Orange Line BRT	Blue Line Light Rail	Gold Line Light Rail	Green Line Light Rail	San Fernando Valley Bus[a]
Cost Per Revenue Service Hour	$243.18	$282.71	$552.54	$440.80	$117.12
Cost Per Revenue Service Mile	$14.53	$12.90	$24.56	$14.37	$9.57
Cost Per Passenger Mile	$0.54	$0.35	$1.08	$0.54	$0.61
Cost Per Boarding	$3.79	$2.45	$7.54	$3.72	$2.26

Source: Los Angeles Metro FY’07 Proposed Budget

[a] Represents Metro Rapid operating costs

Implementation: The simplicity of the Metro Rapid service has allowed almost 450 route-miles to be implemented since the program debuted in 2000. The first two Metro Rapid pilot corridors were launched in just six months. Since the conclusion of the pilot program in 2002, Metro has opened three to six lines per year from 2002 to 2008. Twenty-six lines are in place as of early 2009, with a few more planned. The low investment required also helped speed deployment, since it was easier to secure funding for the new lines. For most of the network, Metro used federal Congestion Mitigation Air Quality (CMAQ) funds matched by local sales taxes. Use of CMAQ funding does not impose the significant oversight burden associated with the usual federal transit funding mechanisms like New Starts. Metro did pursue Small Starts funding for the final few lines, a process less cumbersome than New Starts.

While the Orange Line corridor had a long history of debate and indecision over what to build, once BRT was selected as the preferred mode, the line was built quickly. Planning and engineering took place from 2000 to 2003, and construction occurred from 2003 to late 2005. Metro did not seek New Starts funding, instead relying mainly on state and local funding sources. The agency found it relatively easy to secure funding since because of the high level of enthusiasm from local politicians who participated in the Curitiba trip about implementing a Curitiba-style BRT in Los Angeles.

Capacity: Metro Rapid demonstrates a benefit of low cost incremental upgrades: since these upgrades can be implemented across a very extensive network of bus lines, they offer the opportunity to serve a very high number of passengers. However, both the Metro Rapid and the Orange Line are facing capacity limits with the existing fleets from interaction with general traffic at intersections. Metro reduced Orange Line headways to four minutes at peak hours, and agency officials have indicated that shorter headways are not possible due to concerns over creating back-ups on the north-south cross-streets. Metro had hoped to address this problem by deploying larger buses. In 2007, the agency ordered a prototype 65-ft bus that increases capacity by 20 percent. However, the agency has been unable to obtain the necessary regulatory waivers to operate this bus.

Metro is also looking to add more high-capacity vehicles to Metro Rapid in order to increase capacity without reducing headways. The agency is procuring both 60-ft and 45-ft buses for deployment on Metro Rapid lines over the next several years.

Operating Costs: A 2007 TRB article about the Orange Line documents cost estimates from the transit agency's FY'07 budget. According to this report, operating costs for the Orange Line were comparable to or lower than those of Metro's light rail lines, as detailed in Table 14. The agency does not track Metro Rapid operating costs separately; however, officials report that Metro Rapid's operating costs per platform hour are essentially the same as the San Fernando Valley local bus service, which are much lower than the Orange Line and light rail costs.

Safety and Other Issues: Although the Orange Line has more visible safety issues, its current accident rate is much lower than the Metro Rapid rate. Metro Rapid averages 4.83 accidents per 100,000 miles, while the Orange line averages just 1.45 accidents per 100,000 miles. This is an indication of the greater opportunities for accidents with other

vehicles or pedestrians when operating in general traffic lanes.
Transit-Oriented Development: One rationale for implementing a dedicated busway instead of Metro Rapid lines to serve the San Fernando Valley was the desire to promote development along the segregated right-of-way. As of early 2009, it is too early to tell if the Orange Line will have a significant land use impact, but there are early indications of interest from developers. According to Metro officials, the agency is pursuing several potential joint development projects, and the owner of a new residential building is looking to build a direct connection to the Canoga Station.

Future Plans

The Orange Line's expansion plans are typical of the heavy-investment, single-corridor transit approach. Metro is building a four-mile extension north from the Orange Line's western end to the Chatsworth transit hub, offering a connection to the Metrolink commuter rail. Metro selected a busway built along Metro-controlled right-of-way, rather than on-street dedicated bus lanes, during the Alternative Analysis, continuing the agency commitment to a separated busway for Orange Line service.

Metro has completed Phase I of the Metro Rapid program, but has had to re-consider its plan to implement a higher level of BRT attributes. Agency officials are now indicating that it will be difficult to acquire the right-of-way needed to create on-street dedicated lanes, because such lanes are controversial, even among transit supporters.[53] Moreover, the agency has said that because Metro Rapid operates primarily in heavily built-up areas, it will not be feasible to secure sidewalk space needed to install substantial stations that can allow off-coach fare collection.

However, plans are underway for exclusive lane service along Wilshire Boulevard, Metro Rapid's busiest corridor. From 2005 to 2007, Metro operated peak-hour bus-only lanes on a portion of the corridor, by eliminating peak period curbside street parking, as studies showed sufficient side or off-street parking. Metro is now planning to create roughly nine miles of dedicated curb lanes along Wilshire Boulevard, supported by a federal grant.[54] In addition, Los Angeles County is planning a bus speed improvement program; the county is evaluating corridors where it may be possible to insert short bus lanes or other treatments to improve bus speeds.

SANTA CLARA VTA 522 RAPID: SINGLE CORRIDOR LIGHT BRT

The Santa Clara Valley Transportation Authority (VTA) serves a 326-square mile urbanized region in the San Francisco Bay Area. Often referred to as the "South Bay," the region is home to 1.77 million residents and encompasses a wide variety of land uses, including Silicon Valley industrial parks, universities, low-density commercial and residential areas, and downtown office districts. To serve this sprawling and diverse area, VTA operates 42 miles of light rail service and an extensive network of local bus routes. The South Bay also has regional commuter rail service. However, the region is strongly oriented toward private car travel, with only about 3.5 percent of regional trips taken on transit.[55]

In July 2005, VTA launched its first rapid bus line, the 522. VTA employed a few simple, inexpensive BRT elements designed to provide faster and more frequent service along the South Bay's most popular bus corridor, which runs for 26 miles through six cities in the Santa Clara Valley. The 522 is overlaid onto the local bus service, Rt. 22, but has fewer stops, shorter headways, transit signal priority, and uses VTA's fleet buses marked with a distinct livery. Performance improvements from the 522's mild service and infrastructure upgrades are correspondingly modest, but the service has met its goals of reduced travel times and increased ridership, and at a cost of only $3.5 million or $135 thousand per mile.

The 522 represents the simplest form of incremental BRT in this report with its limited geographic coverage and low level of BRT element implementation. In its focus on a few, inexpensive bus service upgrades, the Rapid 522 most closely resembles the Los Angeles Metro Rapid service. However, Metro Rapid places greater emphasis on image and branding, while VTA invested only in functional service upgrades in a single bus corridor. While the implementation strategy means that even though the 522 is less of a high-profile project than Oregon's EmX and LA's Orange Line, it does demonstrate that a low level investment upgrading conventional bus service can provide benefits.

VTA's recently completed its latest short-term transit plan, covering 2008 to 2017, which laid out the next step in VTA's incremental BRT strategy. The agency plans to add a higher order of BRT features to the 522, including a dedicated busway along a short portion of the route; this level of service has been labeled BRT-2. However, the agency's overall strategy for future transit service is much more dependent on new rail investments than on incremental BRT.[56]

Project History and Goals

For the last 25 years, VTA has had a largely rail-oriented transit strategy. Between 1982 and 2005, VTA built the region's first light rail service, opening nine LRT segments along a 42-mile network. Total cost for the system and its 100 vehicles was $1.9 billion, or $45 million per mile. However, VTA's extensive bus network, with roughly 70 bus lines serving 1,378 route miles, is the "workhorse" of the system, with 31.6 million boardings in 2007 compared to 10.3 million on light rail. Light rail ridership has been increasing at a much higher rate than bus ridership, however: LRT ridership experienced a 22 percent increase in 2006 and 24 percent increase in 2007, compared to 2 percent each year for the bus system. As already noted, the South Valley's transit mode share is relatively low and VTA's customers tend to be heavily transit dependent. A 2006 passenger survey found that 65 percent did not have a car available for their transit trip, and 75 percent take the bus at least four times a week.[57]

The 522 rapid bus line is one of VTA's few major new bus initiatives in recent years. The agency's primary goal was to improve service for existing customers on the Rt. 22 corridor, which is by far the agency's most popular corridor, providing 20 percent of VTA's bus ridership. By supplementing the local service with a rapid transit line, VTA hoped to alleviate crowding on Rt. 22 buses and provide faster, more frequent and more direct service along the corridor. VTA received $1.6 million from the Bay Area Air Quality

Management District's Transportation Fund for Clean Air to pay for queue jump lanes and TSP; the remaining $1.9 million in capital costs was provided through local transit funds. In addition to launching the 522, VTA recently completed a total overhaul of its bus system—the details are provided in the discussion of the 522 elements below —and is now planning to implement a higher order of BRT features in a few bus corridors. These changes are being driven by three major factors. First, VTA's farebox recovery rate is under 15 percent, well below the national average of 36 percent for cities above 200,000 population. This low recovery rate threatens VTA's financial stability and, the agency believes, indicates that transit resources are not being effectively allocated. To address this issue, the agency conducted an analysis of how to reform VTA's bus system, based on market research, operational analysis and policy development. Second, a new transit sales tax was implemented in 2006, which the agency had to determine how best to spend. Finally, VTA was scheduled to develop a new ten-year transit plan, covering FY2008 to FY2017; as part of this effort, VTA conducted a review of all its transit services.

The resulting strategy continues to focus resources on expanding heavy rail service in the South Bay, including a proposed $6.4 billion mega project to extend the San Francisco subway to Santa Clara. By contrast, the short-term plan does not anticipate any significant expansion of bus or light rail in the next ten years. In lieu of major new investments, the plan called for revamping the existing bus service in order to attract more riders and increase the farebox recover rate, and implementing a higher order of BRT features in a few corridors. Upgrades will include all the features of the 522 plus segregated running ways, enhanced stops, bus-passing lanes at stops, and advanced transit signal priority.

Building the 522 Rapid

In this section, we examine the elements implemented on the Rapid 522 and their costs.

Running Way Priority and Routing

The VTA 522 line runs approximately 26 miles along arterial roadways. Its western terminus is the Palo Alto Transit Center, a multimodal transit hub that serves the Palo Alto and Stanford University populations. The route tracks El Camino Real, a regional commercial strip, through several municipalities to downtown San José. It then turns onto Santa Clara Street, another commercial and employment strip, until reaching the residential and commercial area known as Alum Rock. It next turns south onto the Capitol Expressway, ending at the Eastridge Mall. The local service essentially runs the same route, except for a slight extension at the western end past the Palo Alto Transit hub and has significantly more stops. CalTrain, a commuter rail service connecting San José to San Francisco, provides service along approximately three-quarters of the route, with three shared stations. VTA eliminated a former peak period express bus service when it launched the 522.

The 522 route has no augmented running way. The entire line, except for the few times it enters bus stations, runs in mixed-traffic lanes. Thus it has no separation, nor are there special running-way markings associated with this route.

The 522 make 30 stops along this route, at pre-existing Rt. 22 bus stops marked with a

Rapid sign. Stop-spacing for the 522 averages between one-half to one mile, compared to the one-quarter mile between stops for the Rt. 22. This is one of the three treatments designed to improve travel times over the local service; as noted earlier in this report, stop spacing is well-understood to have a major impact on travel times. The 522 Route stops include those serving major shopping areas, the San José CBD, and transit transfer points. These transfer points provide connections to light rail or light rail shuttle buses, regional train service, and local or express bus lines.

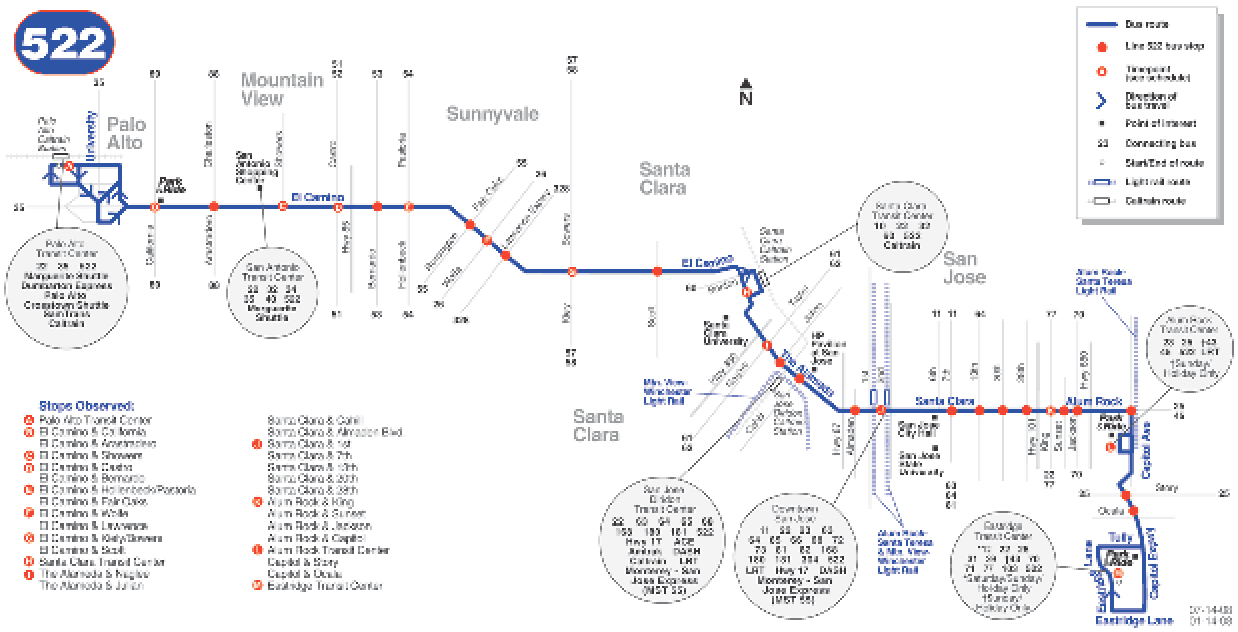

Figure 22 VTA Rapid 522 Route Map
(*Source*: Santa Clara Valley Transportation Authority)

The second major running time treatment is transit signal priority, which the California Department of Transportation (Caltrans) implemented at around 55 intersections. VTA also implemented queue jump lanes at two intersections in Palo Alto. VTA reports that it may add more queue jump lanes at a later date, but for now, this is not a significant feature of the 522.

In 2008, VTA installed an upgraded TSP system at 41 additional intersections, for a cost of $839,000.

In total, VTA spent $2.7 million on the running way treatments, a very modest investment for a 26-mile route. Like the Metro Rapid, the 522 strategy focuses on these low cost upgrades to improve service in an urbanized corridor where it would be a challenge, if not impossible, to create a dedicated running way.

Stations and Fare Policy

The 522 uses the corridor’s existing, traditional station and stop infrastructure. The 26 local bus stops served by the 522 are marked with a “VTA Rapid” sign above the regular bus stop sign, at minimal cost to the agency. This station investment serves only to help riders identify the 522 stops, and does not provide any additional amenity for customers, but is a minor branding element.

The transit center stops are shared with many other bus routes, some from the VTA bus system and some from other bus systems. The stations' layout accommodates multiple buses to board and alight simultaneously, and allows for passing. None has level boarding platforms. The Palo Alto Station has fiberglass overhangs, static passenger information signs, landscaping and lighting. The other transit center stops are less substantial, consisting mainly of sidewalks with bus bulbs where the buses stop.

VTA did not implement any special fare collection. Fares are paid in cash upon entering the bus, or with various passes. The fare structure is a graded, flat rate system.

Figure 23 BRT Branding Signs at Stops
(Photo: Ramses Madou)

Vehicles

The VTA 522 route uses low-floor 40-ft. and 60-ft. buses with conventional exterior styling. The vehicles are of the same stock as VTA's local bus routes, but are wrapped in a red, white and blue livery. The buses also have a conventional interior configuration and entry and alighting channels. The sole expense was the bus wrapping, which cost $130,000. The 522 is the only system in our cases study report that does not use differentiated bus styling as a branding element. The 522 livery functions as a means to distinguish the Rapid buses from local ones.

Figure 24 Palo Alto Transit Station
(Photo: Ramses Madou)

Service Changes

Buses run every 15 minutes on weekdays and Saturdays. Like the Metro Rapid, the 522 operates on a headway-based schedule; this is the final element deployed to improve travel times and service reliability. The service runs from 5:15 a.m. to 9:00 p.m., a shorter span than the local Rt. 22 line that still serves the corridor.

Figure 25 Two VTA Articulated Buses, One with the VTA Rapid Livery
(Photo: Ramses Madou)

Branding and Marketing

Branding for the 522 is basic and functional. The buses, bus stop signage and 522 Rapid materials all feature a consistent design with a red, white and blue color scheme. The branding is designed to let customers easily identify the correct bus and stop to use for the Rapid service, but in no way presents the rail-like image of EmX and Orange Line.

Table 15 summarize the costs for the VTA Rapid Route 522.

Figure 26 Standard Size Route 522 Bus with VTA Rapid Livery
(Photo: Ramses Madou)

Table 15 Categories of VTA 522 Route Costs

Running ways & ITS	$2.7 million
Vehicle wrapping	$130,000
Facilities—station flags	Minimal cost
Other (planning, property acquisition, fare policy etc.)	$550,000
TOTAL	$3.5 million

Source: Santa Clara Valley Transportation Authority

Assessing VTA's 522 Rapid

Travel Times: VTA's primary goal in implementing the 522 Route was to reduce travel time in the corridor. To do this, it increased station spacing, drastically reducing the number

Figure 27 Bicycle Rack on 522 Bus
(Photo: Ramses Madou)

of stops along the corridor, instituted TSP on around half the corridor's intersections, and instituted a headway-based schedule. The 522 has met this primary goal: VTA reports that travel time was reduced by 16 percent on westbound travel and 24 percent for eastbound travel (see Table 16). The 522 provides a 20 percent travel time reduction compared to the local service.

However, it should be noted that the CalTrain is a faster option for longer distance travel along the corridor. A trip from the 522's western terminus, the Palo Alto Station, to the San José Diridon Station about three-quarters of the way along the route takes 31 minutes on CalTrain compared to about an hour on the 522.[58]

Table 16 End-to-End Travel Time Changes for VTA 522

	Pre-BRT	Post-BRT	% Change
Eastbound Maximum Peak Hour Running Time	116 min.	88 min.	-24.1
Westbound Maximum Peak Hour Running Time	120 min.	100 min.	-16.7

Source: *FTA Characteristics of BRT*, April 2009

Ridership: Since the 522 was introduced, ridership in the corridor has increased by 18 percent, from 18,023 average weekday boardings to 21,300 as of 2008. Ridership on the 522 continues to rise; the buses carried an average of 5,200 weekday passengers in 2006; as of February 2008, they were carrying 6,000.

Implementation and Operation: The 522 took five years to plan and implement, a long time for the deployed set of BRT features, but VTA has many other priorities, including rail service. VTA reports that the operating costs for the 522 are essentially the same as for its regular bus service.

Other Bus Improvements: As already noted, in January 2008, VTA launched a bus service restructuring program. The restructuring effort relies on increasing frequency in high capacity corridors, eliminating unproductive lines, consolidating service where possible, and expanding express bus service. VTA also launched an extensive outreach program to ease the transition, including trip planning services via customer representatives and its redesigned website. In February, one month after the changes took place, VTA reported that bus ridership was up by 5.6 percent over the previous February. However, it is not clear how much of this was attributable to the restructuring effort, since VTA's light rail ridership also increased during this time, by 6.9 percent. Moreover, nationwide, transit agencies saw ridership increases during this time due to high gas prices; the national average increase in bus ridership was 2.2 percent, but other agencies saw much higher increases.

Future Plans

VTA and its consultants developed a BRT Strategic Plan that was issued in March 2009.[59] As already noted, VTA plans to upgrade the 522 corridor to what the agency is calling "BRT-2"—several steps beyond the 522 rapid service treatments. This includes putting exclusive bus lanes along some parts of the route where there is car parking now. The Alum Rock Avenue part of the route could eventually be shared with a second BRT line, the 523. Both the 522 and 523 would operate at twelve-minute headways, meaning a bus will be available along the shared running way every six minutes. The further investment in this route is justified because it is at the center of VTA's best market for transit riders – low to middle income residents with fewer transportation options than available elsewhere in the service area. The strategic plan also proposes additional BRT lines eventually, as funding permits, in corridors where existing ridership is strong, future growth is expected, and where no light rail is planned. The ongoing development of BRT is expected to be incremental, for as the strategic plan notes, amenities such as pre-boarding payment of fares will be introduced gradually before all running way improvements are completed.

FINDINGS AND CONCLUSIONS FROM CASE STUDIES

The case studies above illustrate five different approaches to the development of BRT:

- Lane County EmX: Implement a first corridor of significantly improved bus transit that competes with the automobile mode by attempting to be similar to light rail.
- L.A. County Orange Line: Take advantage of the opportunity to implement a high performance bus system on a unique and available right-of-way made bus-only.
- L.A. County Rapid Bus: Systematically upgrade bus service with limited stop, higher frequency overlay service on multiple high volume arterial routes.
- York Viva: Completely revamp the regional bus system around improved limited-stop trunk corridors on key arterials, with conversion to rail possible later.
- VTA Route 522, San José: Inexpensively improve the highest volume bus corridor by establishing a limited stop overlay service with further BRT routes possible.

The case studies illustrate that many approaches to BRT work. All of the above five models contributed to agency priorities and goals.

The case studies also illustrate that BRT is fundamentally incremental, meaning that it is a bundle of characteristics subject to implementation in many combinations, with additional variations possible in the speed of rollout. The incremental character is a fundamental strength: It allows geographic (where), temporal (when), qualitative (what), and sequential (how) flexibility in implementation to match agency goals and constraints, as shown in the case studies.

Many combinations of basic BRT characteristics are possible, and in fact many combinations are seen around North America in the various implementations revealed in the case studies and elsewhere. The case studies show that partial, incremental implementation of BRT yields benefits in corridors where traveler demand exists or develops.

The case studies showed that agencies followed a development pattern recommended in the BRT planning literature: the addition of more frequent and rapid service in the existing highest volume corridor or corridors of the network.

Except for Lane Transit EmX and L.A. County Orange line, the BRT service is a skip-stop limited service overlaid on a regular all-stops bus line. In each case of an overlay, the growth in ridership is taken as the net gain in corridor ridership accomplished with the BRT, net of the reduction in customers on the remaining local all-stops service.

The cases also show in all instances a strong emphasis on the BRT services as mainline trunks into which non-BRT local services feed. The network maps for each case study show the BRT lines intersecting local and feeder lines where transfers can be accomplished.

Motivations for Approaches Taken

The case studies revealed these multiple motivations for the differing agency approaches to BRT development:

- Interest in a less-expensive, less time-consuming approach to public transit in a corridor potentially qualified for railroad service if more resources and political support were available: Lane County, L.A. Orange Line, York Viva.
- At the same time, BRT serves as a line extension or supplement to the rail service that already exists in the region: VTA, L.A. Metro Rapid, L.A. Orange Line, and York Viva.
- Transit agencies in all four case study agencies were responding to a new, lower-cost, high-visibility service delivery concept promoted by a higher level of government. The Federal Transit Administration's Bus Rapid Transit Demonstration Program put a spotlight on the cases of Lane County, L.A. Orange Line, L.A. Metro Rapid, VTA 522, and the Ontario provincial and Canadian federal government were supportive in the case of York, Ontario.
- Availability of previously funded right-of-way was a special key factor for the L.A. Orange Line.
- All the agencies sought a differentiated, higher quality service on selected bus high-volume routes of a transit system, to gain better bus performance and higher ridership.
- Fundamental elements in all case study agencies are peak period high frequencies, early morning through evening span of service, and more widely-spaced stops than traditional service.

In all the cases, the higher expense that would come with adding all possible BRT features caused less than full BRT to be implemented by the time of introduction.

Integration of BRT development with network-wide analysis and potential restructuring occurred in York District, Los Angeles, and Lane Counties. It occurred shortly after the initial BRT deployment with Santa Clara County VTA.

Implication of Case Studies

While in all cases approaching BRT as a corridor solution, the meaning of incremental BRT for the future comes across slightly differently across the agencies:

- Lane County Transit: Add additional features to the first line; then add more BRT lines like the first one.
- L.A. County: Upgrade features; add more features; add more lines.
- York Regional Transit: Upgrade infrastructure; expand branding to the complete bus transit network.
- VTA: Upgrade features; add more lines.

TCRP 90 defines BRT 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." At the same time, these elements could be viewed as a toolbox of improvements that can be mixed and matched into a variety of cost-effective application packages and applied to any bus service, providing substantial travel time and other benefits without meeting the traditional definition of a BRT system.

Over the course of this project researchers picked up informal information from several colleagues that they have concern for "incremental BRT" diluting the hard-won brand image of full-featured transit quality that many BRT initiatives present, illustrated by marketing materials on the web for the Los Angeles County Metro Orange Line, the Lane County EmX, and York Transit Viva among the case study sites. In response, the authors would note that there is no requirement to use the term "BRT" in describing and branding bus service improvements. Indeed, to the degree that only a subset of BRT characteristics are implemented by an agency, it is important *not* to use a publicized term like BRT that may create expectations for total transformation of a bus line when a more limited set of improvements have been implemented.

BRT Disaggregated

In each of the four case studies, transit officials implemented only partial BRT relative to the open-ended potential for more BRT features and more geographic reach, if only greater resources were available. In each case, there is room for incremental improvement in the number and quality of elements such as off-coach fare payment and traveler information. There is also room for more extensive geographic coverage in the service territory of the transit agency.

The variation in concept in the case studies, and the varieties of success experienced not only in the four agencies documented, but in others documented elsewhere[60] leads us to re-conceptualize bus improvement as follows: *In addition to BRT standing as a new mode in its fullest implementations, BRT elements can be considered as a set of speed-enhancing and ridership-attracting features that can be implemented in various configurations, up to and including a total, branded package.*

This is a complete list of potential BRT elements:[61]

- HOV or HOT lanes
- Bus-only lanes
- Median busways
- Queue jumper lanes
- Unique bus identity through coloring and brand name
- Low-floor buses
- More doors and wider doors on buses
- Larger capacity buses
- Distinctive, dedicated BRT vehicle
- More spacing between stops
- Stops specially identified with coloring and brand name
- Level boarding and alighting
- Amenities such as shelters and benches at stops
- Information kiosks
- Next bus displays
- Bus bulbs for boarding/alighting bus in its travel lane
- Simple bus route layout
- Off-vehicle fare collection

- Headway-based schedule
- Frequent service
- Dynamic dispatch operation
- Overtaking policy
- Intelligent Transportation System (ITS) elements
- Automated vehicle location (AVL) system
- Passenger information system
- Transit signal priority
- Electronic fare collection
- Lane-keeping assist technologies

While the emphasis in the BRT literature is that most or many of these characteristics should be integrated on one bus line and given a new brand name, another approach would be to ask which of these characteristics should be implemented widely across the entire network in order to boost ridership and cost-efficiency.

Checklist for Improving Ridership

BRT as a potentially flexible set of characteristics that can each be widely applied as a means to improve ridership is a concept already reinforced by the 2007 TCRP Report, *Elements Needed to Create High Ridership Transit Systems*.[62] It contains many checklists of potential actions that transit agencies can employ, and BRT elements are often listed. For example, Table 2.2 in that report (extracted from the earlier TCRP Report 27 published in 1997), reproduced as Table 17, provides a checklist with the following BRT elements sprinkled among other actions: increased frequency, increased speed, improved comfort, increased capacity, high-occupancy vehicle lanes/facilities, real-time information systems, marketing, and promotion.

Table 17 Elements to Create High Ridership Transit Systems

Category	Type	Strategies
Service Improvements	General	Increased route structure
		Increased frequency
		Service cutbacks
		Dynamic scheduling
		Increased speed
		Improved security
		Improved comfort
		Increased capacity
	Suburb to suburb	High-occupancy vehicle lanes/facilities
		Transportation demand management programs
		Suburban activity centers
	Suburb to central city	Feeder services
		Fare integration
		Service coordination (timed transfers)
		Unitickets
		Station parking provisions
	Within central city	Core services
Information to Customers	Real-time information services	Location
		Schedules
	Low technology	Tailored schedules
		Bus stop information
	Medium technology	Computerized information systems
		Kiosks
Marketing and Promotion		Fare incentives
		Education
		New resident promotion
		image advertising
		Cooperative programs
Public Policy Changes		User-side subsidies
		Parking pricing/regulation
		Income taxes
		Fuel/carbon taxes
		Dedicated operating support
Road pricing		Various

Source: *Building Transit Ridership: An Exploration of Transit's Market Share and the Public Policies That Influence it*, TCRP Report 27, 1997 (p. 8).

Choices—Route by Route vs Flexible Feature Addition

The case studies, supplemented by observations of other deployments of high performance features, show there is a spectrum of choices that transit management has for improving bus service around the elements of BRT, anchored by these two end points:

1. Upgrade selected high-volume routes into a packaged vision of high performance bus service that comes close to previously implemented, widely-publicized configurations of BRT seen in South America, Australia, or Canada.[63]
2. Add BRT features selectively and equitably across an entire bus transit network in a manner that optimizes the result of public investment in transit performance improvement.

Lane County and L.A. Metro Orange Line were influenced by Curitiba, as mentioned in the case studies, and are examples of heavy BRT with a nearly full feature set. More in the middle of the spectrum are York Viva, L.A. Metro Rapid, and VTA 522, with some BRT elements present, and some deferred, either temporarily or permanently. The case studies did not illustrate the second end of the spectrum, but there is a potential for improvement that lies in the cost-effectiveness economics of the issue, as illustrated in Table 18.

The hypothetical BRT development scenarios provided in the *Bus Rapid Transit Practitioner's Guide*[64] highlight the relationships between level of investment in BRT elements, travel time performance, and corridor ridership gain.

Table 18 Performance of Hypothetical BRT Development Scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
	Grade-Separated Busway	At-Grade Busway	Mixture of Busways: At-Grade & In the Arterial Median	Arterial Curb Bus Lanes plus Transit Signal Priority	Arterial Bus Lanes Only	Transit Signal Priority Only
Pre-BRT travel time	94 min	94 min	94 min	94 min	94 min	94 min
BRT travel time	29 min	43 min	48 min	50 min	57 min	58 min
Travel time reduction	69%	54%	49%	47%	39%	38%
Existing base ridership	20,000	20,000	20,000	16,000	16,000	16,000
Final BRT ridership	17,660	15,700	33,020	11,600	10,885	10,815
Final Local ridership	10,000	10,000	0	8,490	8,490	8,000
Corridor ridership increase	7,660	5,700	13,020	4,090	3,375	2,815
Ridership percentage increase	38%	29%	65%	26%	21%	18%
Capital investment cost (millions)	$242	$109	$84.3	$40.3	$12.5	$11.4
Cost per route mile (millions)	$16	$7.3	$5.6	$2.7	$0.83	$0.76
Cost per new daily rider	$32,000	$19,000	$6,500	$10,000	$3,700	$4,000

Source: *Bus Rapid Transit Practitioner's Guide*, Exhibit 5-36, with additional explanation and calculations

Six in-depth different scenarios for using BRT elements to improve the travel time performance and transit ridership in a hypothetical 15 mile urban corridor served by buses are calculated using a variety of expert assumptions and professionally recognized calculations.[65] The scenarios are ordered in the columns from left to right in the order of decreasing investment, and decreasing travel time savings. At the same time, the differences in the bottom row showing capital investment cost per additional rider also indicate a general trend of reduction. The numbers in the chart above illustrate a trade-off between the depth of BRT implementation (number of features) and the geographic extent of implementation.

In other words, for a given amount of resource applied to improvement, doing fewer features on the BRT line(s) before inauguration of service would permit faster and/or more geographically extensive implementation. Given this option, moving forward to improve a single or limited number of corridors with an integrated package of many BRT elements is a focusing decision that reasonably requires justification against the alternative of multi-corridor or network-wide improvements involving a limited number of elements.

In the case shown here, the extremes are marked by Scenario 1, a grade-separated busway for an investment of $32 thousand per new rider, and Scenario 6, transit signal priority by itself for an investment of $4 thousand per new rider. These two examples suggest that a busway for $242 million in one corridor may yield fewer new riders than installing just TSP in ten corridors for $114 million. In a large urban region with multiple high-volume corridors, based on the numbers in Table 18 above, installing TSP in ten corridors across the network could produce over 28,000 new riders compared to fewer than eight thousand in the busway corridor.

The same point can now be illustrated with cost and boarding data for the five systems in the case studies above, shown next in Table 19. If we take the corridor ridership growth attributed by the agencies to the implementation of the heavy or light BRT lines as described, and divide by the capital investment, we see overall costs per new rider in the same range as the theoretical calculations shown above in Table 18. Furthermore, the lower cost treatments associated with light BRT show up similarly to before, having better cost-effectiveness measured by lower capital cost per new daily rider. The light BRT implementations in San José and Los Angeles come in at costs per new daily rider about 1/10 the costs seen in heavy BRT implementations in Eugene and Los Angeles. The cost per mile of route coverage with the L.A. Metro Rapid is 1/100 the cost of the Orange Line in the same jurisdiction, which is reflected in the features and quality of the two implementations: Orange Line is much more train-like. On the other hand, the Metro Rapid approach to bus improvement covers 33 times more route miles than the Orange Line.

Table 19 Performance of Five BRT Development Experiences

	L.A. Metro Orange Line	Lane County EMX Green Line	York Viva	VTA Route 522 Rapid	L.A. Metro Rapid
	Median busway with TSP	Median busway with TSP	On-street running with TSP	On-street running with TSP	On-street running with TSP
Travel time reduction	16%	6%	11%	20%	25%
Baseline corridor ridership pre BRT	41,580 (2005)	2,700	19,400	18,023	388,400 (2000)
Cited corridor ridership after BRT implementation	62,597 (2007)	5,400	45,000	21,300	464,400 (2007)
Corridor ridership increase	21,017	2,700	25,600	3,277	76,000
Ridership percentage increase	51%	100%	132%	18%	20%
Capital investment cost (millions)	$350	$24.5	CA$172	$3.5	$110
Route miles	13.5	4	50	26	450
Cost per mile (millions)	$26	$6.1	CA$3.4	$0.13	$0.24
Cost per new daily rider	$16,700	$9,100	CA$6,600	$1,100	$620

Source: Case study data in this report. TSP means transit signal priority.

The hypothetical and real examples of wide geographic coverage at a lower cost per mile and per new boarding versus the alternative of more extensive and expensive improvements in a limited geography suggests a structure for thinking about BRT incrementalism.

Dimensions of Incrementalism in BRT

The two dimensions of incremental BRT deployment—geographic coverage versus number of BRT elements in limited deployments—are illustrated in Figure 28.

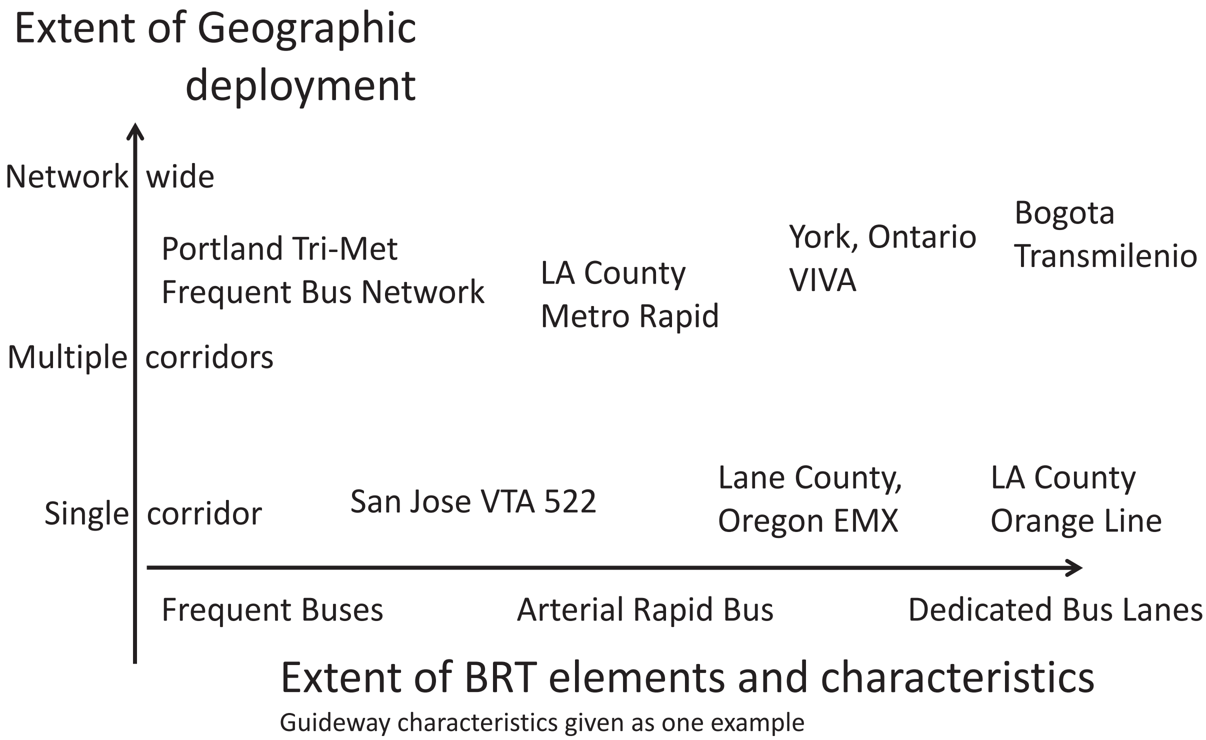

Figure 28 Dimensions of BRT Incrementalism
(*Source*: Global Telematics)

One dimension, shown on the horizontal x-axis, is the number of BRT characteristics embraced in a particular BRT implementation. The degree of transit exclusivity on the guideway is shown as an example, but any BRT characteristic could be substituted, such as transit signal priority (TSP) or off-coach fare collection. Both the particular characteristics chosen, and the quality and degree of implementation are relevant here. For example, TSP at the low end would be static signal progression where the timing is set to reflect bus movement. TSP at the high end would be dynamic sensing by signal controllers of how late a bus is running, with the signal responding individually to the situation of every late bus to help put it back on schedule.

A second dimension, on the vertical y-axis, is the geographic coverage of the BRT deployment in a transit agency's service area.

The five case study implementations are shown on the graphic. VTA 522, Lane County's EmX, and the L.A. Orange Line are single corridors shown in order of an increasing number of BRT features from left to right. The L.A. Metro Rapid and York Viva are shown as multiple corridor systems in the same order of features. We have also shown the Portland Tri-Met Frequent Bus Network as a multi-corridor improvement that is focused primarily on lowered headways,[66] a single feature of BRT which amounts simply to more service hours on a route. Far to the right on the graphic is the Bogota, Colombia Transmilenio system, a city-wide full-featured BRT including dedicated guideways and extensive station stops with level boarding.[67]

Complete Disaggregation and Network-Wide Implementation

An incremental viewpoint on BRT means grasping that the various BRT elements can be disaggregated and considered separately for implementation across an entire transit network, in addition to consideration of route by route deployment. Examples are shown in Table 20 below.

Table 20 Examples of BRT ElementsThat Can be Applied on Multiple Routes Without Necessarily Being Integrated with Other Elements

Speed coaches along arterials with transit signal priority.
Use queue jump lanes to move buses past congestion at intersections.
Invest in partial or complete exclusivity of buses in the travel lane to move buses faster than in congested general purpose lanes.
Add more appealing coaches; for example, larger, low-floor buses.
Reduce dwell time by off-coach payment systems.
Implement more frequent service.
Remove some bus stops, leaving the remainder more far apart, with full consideration of the trade off in customer access by walking.
Add skip-stop limited service on the same route as regular all-stops service.
Add express runs in the peak direction of the peak period between major origins and destinations.
Create a branded, higher class of service on some routes.
Add new routes, such as limited-stop, cross-town trunk lines.
Add ITS features such as real-time station displays of minutes until the next bus, or central monitoring of coach locations to keep headways uniform.

Source: Global Telematics

To recapitulate: Unbundled, disaggregated BRT attributes can be a tool for transit improvement aimed at increasing ridership for a reasonable cost. At the same time, deep incrementalism is an option—meaning the rapid implementation of specific BRT features across the entire network.

BRT can thus be reconsidered as a suite of characteristics that singly or in combination create a faster, more reliable, and more attractive bus-based mass transportation mode at a cost that invites geographically extensive application.

Hess, Taylor, and Yoh studied the cost factors in a sample of heavy and light BRT systems and found considerable potential in the lower cost features, illustrated by one of the first Los Angeles Metro Rapid lines:

> Our analysis of disaggregated BRT costs for 14 transit agencies shows that, with the exception of exclusive rights-of-way and stations, most BRT service improvements are relatively inexpensive to implement. For example, next-bus indicators—which

range in this sample from $6,000 to $53,000 per stop—can substantially reduce the perceived burden of waiting and transferring, while signal-priority systems can increase speeds (thereby lowering the number of vehicles and drivers needed to provide a given level of service). The wildly successful Wilshire Boulevard BRT in Los Angeles, which increased corridor transit ridership by one-third, is an example of such low-cost service.[68]

As another example from the case studies above, VTA's experience with light BRT highlights the impact that increasing stop spacing has on decreasing running time. Comparisons of bus service between North America and Europe indicate that there is an extensive opportunity for wider stop spacing.[69] Analytical work in Portland, Oregon illustrates that the costs in longer walks to stops by some customers can be equitably traded off against higher travel speeds resulting from fewer bus stop locations.[70]

The highly-regarded *Eddington Transport Study* in the United Kingdom found that small, incremental improvements tend to have higher cost-to-benefit ratios than large, infrastructure-intensive projects. This study noted, "it can often be sensible to invest in a collection of smaller, high-return, projects rather than a single large one, although portfolios of smaller projects do need to be managed carefully to deliver large-scale aggregate benefits in this way."[71]

Managing a collection of smaller improvements in a bus network requires understanding how BRT elements relate to optimizing the entire transit system, the topic of the next chapter.

BRT IN RELATIONSHIP TO TRANSIT NETWORKS

To summarize the argument to this point, the case studies of four agencies, while illustrating diverse approaches, only begin to suggest the many choices in how to proceed with BRT. Going deep by adding many BRT elements in the busiest existing corridor is one choice, but so is a less deep implementation of BRT features, or even a BRT light or "very light" implementation across many corridors. In other words, an available opportunity is to add high-value BRT elements to many lines simultaneously, rather than layering multiple features into an integrated package on a single line.

However, there is a danger in incremental, piecemeal bus network improvement, especially where guideway infrastructure is concerned. That danger is sub-optimization of the total system by foreclosing future options with incremental steps taken in the present day. For example, heavy BRT implementation in particular corridors may lead to a commitment to a route structure that is too soon revealed as suboptimal. Caution is indicated in recent research findings that typical and traditional CBD-focused bus networks offer lower performance than networks which focus on connectivity between a more complete set of the major urban and even suburban centers and institutions that happen to be the origins and destinations for many trips.[72]

The goal is to support an optimal development path of the transit network—gradual transformation of the route structure to better serve a growing number of origins and destinations as population and employment grow. As Vuchic points out: "Bus services should be planned and operated as systems, rather than as a set of buses placed in service on certain alignments. Their ROW, stops, vehicles, and operations must be integrated in efficient transit systems."[73]

Transit leaders who seek to implement BRT characteristics across the complete network rather than in a limited number of corridors have a vast range of choices in sequencing the development and deployment of disaggregated BRT elements. One obvious insight is that a focus on improving the overall performance of the complete transit network best guides the choice of how to proceed. In other words, there is an opportunity to fit incremental deployment of BRT elements into a framework of overall transit network improvement aimed at improved connectivity, ridership, and cost-effectiveness.

Basics of Transit Networks

Public transit bus route networks have typically evolved over time, responding gradually to changes in residential and commercial land development, road infrastructure, and travel patterns. Many urban bus routes follow the path of long-removed electric street railroads.

The traditional template of transit network planning includes evolution toward high-volume trunks (that may be rail) running between urban centers. Passengers for the trunk lines come from origins within a half mile or so of the line, and also by transfers from lower capacity feeder and circulator lines—usually buses, or occasionally streetcars. The orientation of trunks is to center city and other educational and commercial concentrations generating daily two-way traffic.

The corridors are invariably delineated by the urban road network of highways and arterials that supports the dominant mode of travel, private automobiles and trucks. Urban land development and the road network mutually shape each other, because of the dominant support provided to all commercial, educational, and recreational activity by personal and goods movement in cars and trucks. However, the roads are also available for bus service, a way for some travelers to reach all key origins and destinations on public transit, using the same roadway infrastructure as the cars and trucks that provide the majority of movement in North America.

HOV lanes and in rare instances, bus-only lanes, are sometimes built as part of urban roads, especially for new expressways, tunnels, and bridges. The case studies above provide examples of bus-only lanes in Los Angeles and Eugene, Oregon. Inclusion of technology for more controlled and managed traffic flows, including road user fees with peak-period premiums to motivate more off-peak travel, is a likely future trend that is favorable to the movement of buses.[74]

Factors in Designing Bus Service Networks

As shown in Table 21 from the TCRP Synthesis report *Bus Route Evaluation Standards,*[75] there are traditional, existing standards that organize the many factors that govern the design of bus route networks by transit agencies. The standards cover design of routes and schedules, economics and productivity, service delivery, passenger comfort, and safety.

Table 21 Bus Network Design Standards

Route Design Standards: Under the route design category, 15 criteria are used in designing or redesigning a routing. These criteria, which help determine and establish the buses' pathway, are as follows: Population density; Employment density; Spacing between other bus routes and corridors; Limitations on the number of deviations or branches; Equal (geographic) coverage throughout the local tax base; System design considerations such as enhancement of timed transfers; Streamlining/reduction of routing duplications; Network connectivity; Service equity; Route directness; Proximity to residences; Proximity to non-residential generators; Limitation on the number of transfers required of riders; Bus stop siting requirements; Bus stop spacing requirements.
Schedule Design Standards: The criteria under schedule design are used in designing or redesigning a route's frequency, and help determine and establish the scheduled interval between buses as well as the starting and ending time of service on a given day (span of service). These criteria include the following: Differing levels of service, i.e., local service versus express service; Differing character of service, e.g., crosstown versus feeder; Maximum number of standees; Maximum intervals; Peak periods versus off-peak periods; Minimum intervals; Standees versus no standees; Duration of standee time; Timed meets, or time to be spent waiting at a transfer point; Use of clock-face schedules; Span of service.
Economic and Productivity Standards: The first two categories of standards, route design and schedule design, dealt with criteria that lead to the design or redesign of a service. Economic and productivity standards include criteria that measure the performance of an already existing service. The criteria are as follows: Passengers per hour; Cost per passenger; Passengers per mile; Passengers per trip; Passenger miles; Revenue per passenger per route (either in absolute dollars or as a percentage of variable cost); Subsidy per passenger; Route level minimum variable cost recovery ratio; Route level minimum costs that also include semivariable and/or fully allocated/fixed costs; Route level performance relative to other routes in the system.

Service Delivery Standards: The criteria for this category of standards measure service reliability. Service delivery criteria include the following: on time performance and headway adherence (evenness of interval). These criteria measure a route's service as actually delivered to a passenger…. some transit systems use these criteria at a system, not bus route, level.

Passenger Comfort and Safety Standards: The following criteria measure the ambiance that greets a rider using the bus system:

Passenger complaints; Missed trips; Unscheduled extra buses or trips; Accidents; Passenger environment conditions (e.g., vehicle cleanliness, vehicle condition, missing stanchions, blank destination signs); Special information (or special intervals) in areas where riders do not feel secure waiting for buses.

Source: Excerpt from *Bus Route Evaluation Standards,* TCRP Synthesis 10, TRB, 1994, pp. 6–8.

Making a more summarized case for essential characteristics, Beimborn and colleagues[76] note that in order for a person to use public transit, all of the following six conditions must be met:

- Knowledge: User must have knowledge about how to use the service
- Connectivity: Service connects users' origin and destination
- Access: User must be able to get to the stops at both ends of the trip
- Schedule: Service operates at appropriate times
- Boarding: Users must be able to get on and off the vehicle with all they carry
- Security: User must feel safe and secure.

Notice that "speed or "faster than by private automobile" is not one of the conditions listed. In fact, an analysis of household travel diary data from Portland, Oregon, reported in the same paper confirms that among travelers who have a car to use and choose transit, the slower speed of a bus trip compared to driving was not important in the choice to use transit. More important is easy physical access to the transit system, and the amount of time spent waiting for buses to arrive, especially at transfer points.

Connectivity, access, and schedule in Beimborn's list are the important concepts related to BRT elements. These three conditions support an incremental approach to better bus service that favors geographic reach over full-featured BRT lines covering less territory.

Process of Designing Bus Transit Networks

The overall process of designing a bus transit network was laid out in the 1980s by Ceder and Wilson[77] as following these steps in normal practice: designing the routes of the buses, setting the headways (frequency) of the buses, developing the timetable, scheduling the buses, and scheduling the bus drivers.

A diagram produced by Fan and Machemehl[78] illustrates the input data and results of the process (Figure 29, next page).

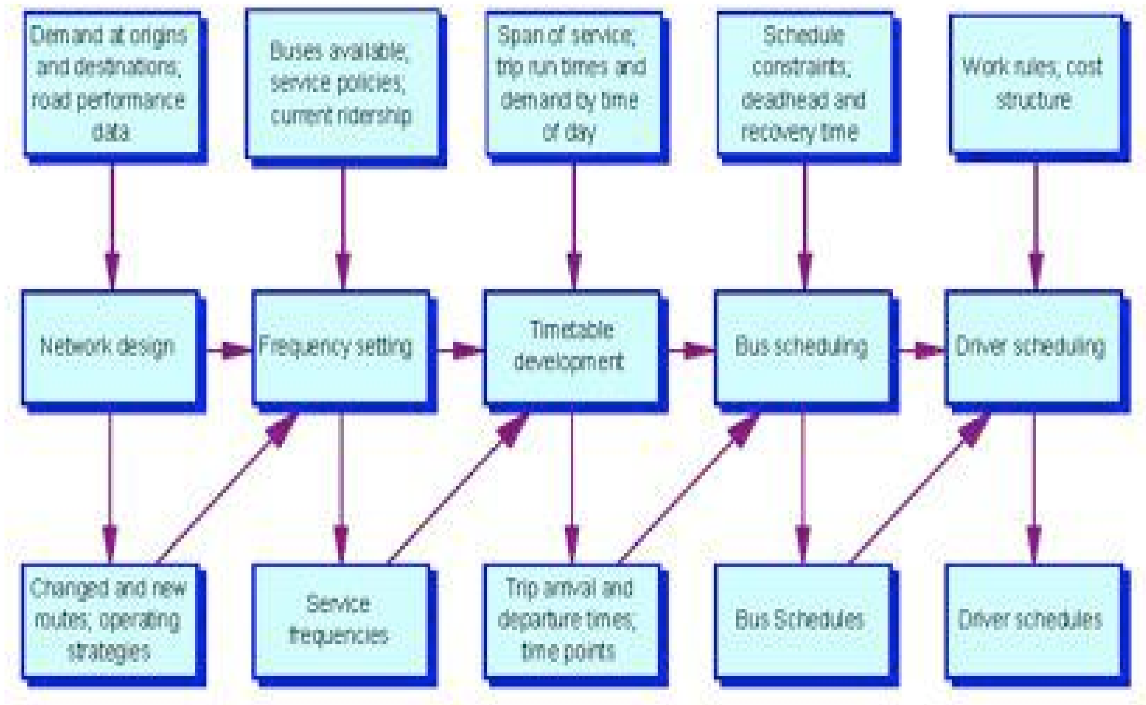

Figure 29 Bus Planning Process

(*Source*: adopted from diagram by Wei Fan and Randy B. Machemehl, *Optimal Transit Route Network Design Problem: Algorithm, Implementations, and Numerical Results*, Center for Transportation Research, University of Texas at Austin, May 2004, Figure 1.2, who in turn were depicting and modifying an illustration from Ceder and Wilson, 1986.)

The researchers' interest in this present study of BRT elements is primarily the first two parts of the process, the left hand two columns in the above diagram: network design of the bus routes and setting service spans and headways on the routes. These steps would be guided by agency goals and constrained by agency resources. As pointed out by Guihaire and Jin-Kao Hao,[79] the network as it already exists is an important starting point. However, improvement is generally possible, as pointed out by Pratt and Evans:

> The increasing dispersion of urban activity and related travel brings with it the need to critically examine existing systems and investigate not only crosstown and reverse commute bus routes along with extension of existing routes, but also alternative forms of overall system design. Bus system designs that can be readily customized to individual land use and travel patterns (such as hub and spoke systems) appear to have a slight edge over more purely geometric configurations (such as grid systems) in their success rates. Finding non-downtown oriented travel corridors of sufficient trip density to support conventional bus service can be difficult. …
>
> It follows that enhanced success rates in bus route and system design and redesign should be achievable if quantitative investigation of travel patterns and their relationship to proposed bus service configuration is built in to the process.[80]

EVOLVING TOWARD A BETTER NETWORK

While the case studies reveal a process of implementing multiple BRT elements in an integrated package on a line by line basis, a reasonable alternative approach to network improvement is the addition of selected high-value BRT elements across the board on multiple lines—for example, off-coach fare collection, or higher frequency limited stop service.

An important concept emerges: *making sure that incremental investments in BRT elements to improve existing transit routes are consistent with a development path toward an overall improved network.*

NETWORK IMPROVEMENT THROUGH INCREMENTALISM

There are many existing methodologies and transit agency practice examples of analyzing an existing transit network to specify bus route changes that provide better connectivity and ridership gains.

The four case study agencies illustrate these practices:

- Los Angeles County Metro engaged in a structured selection process for identifying its Metro Rapid arterial lines beyond the first two demonstration lines. A first screening of all lines in the county was conducted against what are called “Tier One transit criteria”: lines that serve major regional corridors, provide key network connections for longer distance travel, and have high ridership. A second screening developed a ranking of Tier One lines based on a combination of these measures: weekday unlinked passengers, average passenger trip length, revenue operating speed, annual passengers per route mile, weekday seat utilization, weekday riders retained on weekends, weekday passengers per bus hour, operating ratio. Finally, the lines that scored well on these measures were evaluated for ability to support the high Metro Rapid frequencies, whether the corridor currently has multiple levels of regional service (e.g., express, limited-stop, local, and community), and whether it is at least one mile from parallel rapid transit lines. By this process, officials identified 22 additional lines for Metro Rapid overlay service.[81]
- Lane Transit District in Eugene, Oregon has a 60-mile network of BRT corridors laid out, with a 20-year plan to replace existing bus service along these corridors with BRT trunk lines like the EmX. This network is illustrated in Figure 8 in the case study above.
- York Transit District in Ontario, Canada is working off a master plan that has reorganized bus transit to provide Viva BRT service along two main corridors that connect four main urban centers within the York District. Circulator and feeder lines covering other areas provide connection to the stations of the Viva lines.
- Santa Clara Valley Transportation Authority in San José has recently engaged in a “Comprehensive Operations Analysis” to reallocate resources toward more ridership and higher fare box recovery, while leaving the overall level of bus service system-wide the same. The agency examined all its existing bus lines to identify find those with below average ridership, and then some of these were consolidated into other lines or deleted. Service hours thus freed up would be reallocated to enhancing service on well-utilized lines with the potential for increased ridership. The intent was to provide more frequent and faster service to the majority of VTA bus riders, especially during off-peak hours and weekends.[82]

In all these agencies, planners have conducted public consultations in order to understand customer attitudes and desires not picked up in surveys and statistics.

Academic researchers have also developed techniques for systematically expanding transit networks as a region grows. For example, Matisziw and colleagues developed a method using data from geographic information systems (GIS) entered into a computer-based model to extend an existing transit system through prioritizing route and stop additions. They demonstrated and documented its use for transit system in Columbus, Ohio.[83]

Backbone Trunk Quality as Central

As described in the TCRP document *Developing Guidelines for Evaluating, Selecting, and Implementing Suburban Transit Services*,[84] a traditional route classification scheme includes trunks, feeders, shuttles, express services, circulators, and limiteds. In a corridor-focused approach, BRT can be considered as a type of skip-stop, limited service, which in turn is one variety of a trunk line.

There is a significant issue in network design, namely, whether the configuration should feed passengers in outlying areas into transfer centers providing high volume, high capacity service to major activity centers, or should the network design emphasize one-seat rides through minimization of transfers between vehicles. Transit customers generally view transfers negatively, as illustrated in the following discussion from a TCRP report of how validated, analytical models treat transfers:

> …choice of mode is typically found, in mode choice model estimation, to be more sensitive to out-of-vehicle times overall (walking and waiting combined) than in-vehicle (running) time. A majority of models show a sensitivity to out-of-vehicle time overall that is in the range of 1.5 to 2.3 times the sensitivity to in-vehicle time. Some but not all of newer models utilizing new techniques and approaches to fine-grained measurement of out-of-vehicle time components exhibit even higher out-of-vehicle time sensitivities.[85]

On the other hand, a transit network structure that consolidates passengers from feeder services into high volume trunk lines is thought to provide operating efficiencies, a concept that is a central justification of large city systems that operate rail spines to feed major centers.[86] Interestingly, bus-based systems provide the option of both kinds of design—either emphasizing one-seat rides, or emphasizing a stem-trunk system that focuses on transfers for efficiencies.

The Quickways Vision

One future urban bus transit networks concept that minimizes transfers has been articulated by Alan Hoffman.[87] His network designs create a mesh of short headway, high frequency BRT trunks with feeders running at a frequency appropriate to demand levels. Some of the feeders can be the BRT buses in the outer reaches of the network, traveling on ordinary arterials before reaching the higher frequency trunk line part of the route. The trunk lines emphasize bus priority in the face of higher traffic volumes associated with employment centers and other congested destinations.

Both bus and rail network designs permit branching extensions coming off a main corridor in a dense urban zone. Multiple routes with interleaved headways on the main corridor guideway can efficiently serve a high concentration of riders. Multiple routes on a single guideway are a network design element exploited by the Bogota Transmilenio BRT system.[88]

One approach to this design concept for bus transit as developed by Hoffman in a draft plan for San Diego is the Quickways concept, a heavy BRT system-level concept that exploits the flexibility of buses to operate on all kinds of streets.

Hoffman lists the key characteristics of the Quickway configuration as follows in his report, quoting:

1. Created around a dedicated, often grade-separated right-of-way;
2. Employing major stations along that right-of-way, and occasionally off that right-of-way as well, which incorporate passing facilities so that some routes may bypass individual stations;
3. Less dependent on advanced transit vehicles;
4. Less dependent on advanced signaling and traffic management systems, as well as advanced passenger information systems;
5. Benefiting from advanced or off-board fare collection, but less dependent on it to achieve travel time savings;
6. Employing a robust and multi-route service pattern, designed to deliver the largest number of passengers to key destinations with a minimum of transfers; and
7. Focusing branding and identify more on the infrastructure and less on the vehicles.[89]

This list from Hoffman immediately suggests incremental BRT in downplaying characteristics like electronic systems, while emphasizing others, such as exclusive guideways for buses. The Quickways approach emphasizes a step-change in transit performance via the provision of significant investment in grade-separated, bus-only guideways in the dense center(s) of an urban network. Hoffman's intent in his specifications is to create a beneficial operating environment that generates lower operating costs per passenger by moving passengers quickly and at high coach load factors. The speed, reliability, and frequency of service may even support a premium fare.

Pursuit of a Quickways-based system is a good example of seeking a long-run vision that intends to avoid incremental sub-optimization of overall connectivity by emphasizing total network design as the first priority. However, the Quickways vision of dedicated guideways may be too costly a capital investment for some agencies in the near and mid-term. The examples in the case studies suggest that selective investments in lower-cost BRT characteristics across an entire network could also yield returns.

In summary, the larger pursuit for a bus-based network must be improved performance outcomes for the entire transit network; BRT elements—or characteristics—are tools, not ends in themselves. Applying a few BRT characteristics flexibly and widely is just as valid as the traditional approach of applying many characteristics on a selected line.

RECOMMENDATIONS

These recommendations are made from the results of this study:

- Given the critical need to grow transit usage supported by appropriate capacity and service characteristics in a changing economic environment while reducing operating deficits, it follows that improved productivity of operations—measured by customers per revenue hour—must be a central focus of transit improvement, whether via implementation of BRT elements, or by other means not covered in this report.
- In addition to the traditional view of BRT as an integrated package to be applied in high volume corridors, transit agencies should also consider the option of extracting a subset of the most affordable and beneficial elements from the available suite of BRT elements. Individual elements can then be flexibly applied system-wide. This option is compatible with the culture of continuous improvement sought in APTA's sustainability program,[90] and also fits well with the findings of the Eddington Report from Great Britain.
- Especially when taking a more incremental approach to bus transit improvement, transit managements need to set the path of BRT development with an initial understanding of the performance of the present transit network, and then be guided by a clear view of a preferred future network. Incremental changes should provide evolution toward that future network.
- In the FTA New Starts and Small Starts programs, the underlying, mandatory corridor-focus for New Starts transit capital investments[91] should be expanded to include more flexible, network-wide approaches as described here.

Suggestions for Further Research

The following topics are worthy of additional research:

- Specific performance implications of particular BRT features, such as expanded stop spacing, off-coach fare payment, queue jump lanes, and low-floor buses should be assessed. What ridership and efficiency gains does an agency get from each feature? Which elements should be emphasized in an environment of limited resources? Several of the authors of the present study are at this writing engaged in follow-up research for Federal Transit Administration on this question.
- On particular feature of BRT is more frequent, all-day, limited-stop service. Even with buses moving faster along the route, higher frequency and lower headways will generally require increased service hours, especially when overlaid on top of a regular, existing service that is partially retained. Each of the case studies showed ridership increases but with the exception of Lane Transit, they also required increased service hours for the corridor, the sum of the new BRT service and the regular service retained. The additional service hours increase ridership, but an associated issue is the change in service productivity, measured by boardings per service hour. A future research project should separate the influence on ridership of service hours and associated headways from other BRT amenities such as newer, more attractive coaches and station stops.
- Do the various features of BRT always synergistically interact for a positive outcome? Are there features with maintenance requirements that detract from overall cost-effective

performance in some way? For example, some electronic sign displays of time-until-next-bus have been observed by the authors to be inoperative at BRT stations that are not part of the case study systems.

- Is low-level incrementalism in BRT development with new features added sequentially over a period of years inherently less effective in gaining higher ridership than implementing larger bundles of BRT elements all at once in order to get a “big bang” of noticeable changes that gain customer attention, appreciation, and embrace?

CONCLUSION: A PATH TO BETTER TRANSIT

The case studies suggest that many paths lead to bus improvement. All of the five models documented in the case studies showed ridership growth, at most moderate cost growth, and thus the potential for growing the cost-effectiveness of service through more passenger trips per revenue mile of service. As a whole, these case studies indicate diverse paths to public transit improvement. In particular, there should be no automatic compulsion to make implementation of higher quality bus service into a search for where to develop a full-featured, heavy BRT line.

As shown in several of the case study examples, rapid transit services are typically planned and implemented on a corridor level. Under this model, required by law for federal grant funding support, a corridor is identified, an alternatives analysis is conducted, and a locally preferred alternative is selected and implemented in that corridor. Although corridor-level planning serves the requirements of rail transit, a geographic focus limited to one corridor is not necessarily the best model for bus service improvement, notwithstanding that BRT developed this way has frequently led to ridership improvements.

An insight emerging from this study is that selected BRT elements can also be implemented flexibly across an entire bus service network, as seen in Los Angeles with multiple Metro Rapid lines, and in Portland, Oregon with TriMet's Frequent Service Network, mentioned earlier. The vivaNext program in York, Ontario is planning to implement some of its BRT amenities throughout the Transit District. Such an approach can be subject to design constraints aimed at achieving more new transit trips per dollar of investment than would be the result from bearing down with an integrated system of many BRT features in one or just a few corridors.

But to guide development, a complete network wide system of quality bus service should first be envisioned and planned. Defining a future network that also responds to regional land development policy is best. Incremental, step-by-step upgrading of the entire system with targeted deployment of BRT features creates an optimal path of ridership growth for the entire transit network.

Overall, the authors recommend reconsideration of the implicit proposition in bus transit performance improvement that the corridor-level BRT planning paradigm is the obvious choice for developmental action. As this process is now incorporated in the laws and regulations governing federal capital funding of new transit projects, the planning process forces communities into thinking on a corridor level. Given the ability of the elements of light BRT and even heavy BRT to be applied across multiple corridors at investment levels traditionally considered appropriate for a single corridor, now is a good time to make the FTA process more flexible.

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ABBREVIATIONS AND ACRONYMS

APTA	American Public Transportation Association
AVL	Automatic Vehicle Location
BRT	Bus Rapid Transit
CA	Canadian (as in Canadian Dollars)
CBD	Central Business District
CBRT	*Characteristics of Bus Rapid Transit*
COST	Citizens Organized for Smart Transit
FTA	Federal Transit Administration
GIS	Geographic Information System
HOV	High-Occupancy Vehicle
ITS	Intelligent Transportation Systems
LTD	Lane Transit District
PPP	Public-Private Transit Partnership
ROW	Right-of-Way
TCRP	Transit Cooperative Research Program
TOD	Transit-Oriented Development
TSP	Transit Signal Priority
TTC	Toronto Transit Commission
VTA	Santa Clara Valley Transportation Authority
YRT	York Region Transit

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