Wake County Transit Plan MIS

BRT Peer Review
# TABLE OF CONTENTS

1 Introduction.......................................................................................................................... 1  
   Key Takeaways ..................................................................................................................... 1  
2 Peer Systems ......................................................................................................................... 3  
3 Core BRT Elements.............................................................................................................. 13  
   Dedicated Right-of-Way ....................................................................................................... 15  
   Center-Running Alignment ................................................................................................. 16  
   Off-Board Fare Payment ..................................................................................................... 17  
   Signal Priority at Intersections ............................................................................................ 18  
4 Key Benefits of BRT.............................................................................................................. 19  
   Travel Time Savings ........................................................................................................... 19  
   Ridership Growth ............................................................................................................... 20  
   Economic Development ....................................................................................................... 21  
5 APPENDIX .......................................................................................................................... 25  
   Core BRT Elements and Benefits ....................................................................................... 25  
   Other BRT Elements ........................................................................................................... 28  

# TABLE OF FIGURES

- Figure 1: Core BRT Elements by Peer System .................................................................... 14  
- Figure 2: Grade-Separated Pittsburgh Busway .................................................................... 15  
- Figure 3: EmX BRT with Center Alignment ......................................................................... 16  
- Figure 4: Off-Board Fare Payment for Swift ...................................................................... 17  
- Figure 5: Transit Signal Priority .......................................................................................... 18  

Nelson\Nygaard Consulting Associates, Inc. | ii
1 Introduction

Bus rapid transit (BRT) is a flexible, high capacity transit solution that combines physical and operational elements to improve transit travel times and reliability. As Wake County moves forward with the implementation of the Wake County Transit Plan, it is crucial to examine existing BRT systems to identify elements that led to their success. A mix of different peer systems were chosen that represent different investment strategies, ranging from busways and fixed-guideways to minimal infrastructure investments. Each has a potential lesson for the benefits of differing investment levels in Wake County. The following peer systems include:

- RTA HealthLine (Cleveland, OH)
- Metro Orange Line (Los Angeles, CA)
- LTD EmX (Eugene, OR)
- Community Transit Swift BRT (Snohomish County, WA)
- Albuquerque Rapid Transit (Albuquerque, NM)
- KCATA MAX (Kansas City, MO)
- Metro A Line (Minneapolis, MN)
- South Miami-Dade Busway (Miami-Dade County, FL)
- Pittsburgh Busways (Pittsburgh, PA)

This report presents a brief overview of peer systems, identifies differentiating elements of BRT, and details the benefits experienced by each system from incorporating these elements. A primary focus for each BRT is benefits such as travel time savings, ridership growth, and economic development. Areas such as fares are not a focus, as all BRT peer systems had identical fares to local service.

KEY TAKEAWAYS

Wake County has the opportunity to incorporate elements of BRT that will set the stage for a robust, effective, and attractive system. Based on the benefits of BRT experienced by peer systems, Wake County can learn from the following key takeaways:

- **All BRT lines reduced travel time.** A large portion of the travel time savings were due to increased stop spacing. The peers with the largest travel time savings also had the widest bus stop spacing. Dedicated lanes, transit signal priority (TSP), and off-board fare payment were also factors in reducing travel times.

- **All BRT lines showed increased ridership.** The BRT systems with the largest immediate impacts had the highest levels of infrastructure investments and experienced a 50% or more ridership increase within a year of opening. The combination of dedicated right-of-way, off-board fare payment, and TSP contributed to this improved ridership. BRT has
the greatest potential for success when core elements are implemented in tandem. In addition, economic development that precedes or accompanies the inception of BRT can foster increases in ridership due to increases in employment, population, and overall activity along the corridors.

- **The economic development results were mixed.** The Orange Line in Los Angeles and HealthLine in Cleveland helped generate billions of dollars in development. In its first several years of operation, Albuquerque Rapid Transit (ART) is anticipated to generate millions of dollars in development along the corridor. All three of these corridors represent some of the highest levels of capital infrastructure investments. As a comparison, Kansas City’s MAX experienced limited economic development along its alignment when compared to its peers. The peer cities’ experiences suggest a symbiotic relationship between the level of economic development and capital investment. BRT has the ability to spur economic development when it is implemented with quality features.
2 Peer Systems

This chapter provides a brief overview of nine peer systems. BRT covers a wide spectrum of applications. The peer systems in this study are categorized into three groups: Full BRT, BRT Lite, and Busways.

- **Full BRT** typically incorporates exclusive lanes, off-board fare payment, level boarding platforms, transit signal priority, defined stations, and branding. Full BRT provides services and amenities most similar to rail service without the high costs.

- **BRT Lite** is an improvement over local bus service. It typically runs in mixed traffic but does not always include off-board fare payment or defined stations. BRT Lite employs low-cost applications to improve speed and reliability.

- **Busways** are exclusive guideways that improve speed and reliability for buses. Busways allow multiple bus routes with limited stop service to operate along a dedicated corridor.
**HealthLine**

**RTA - Cleveland, OH**

The HealthLine consists of one, 7.1-mile route, which has been operating since 2008. The project cost $199.4 million, or $28.1 million per mile. Of the $199.4 million, $168.4 million was executed through a Full Funding Grant Agreement (FFGA). The remaining $31 million consisted of non-FFGA funds from the Ohio Department of Transportation, local funds, and the Cleveland Clinic (a non-profit medical center). The HealthLine operates with five-minute frequencies during peak periods at an average speed of 10 miles per hour (mph).\(^1\) According to the Institute for Transportation & Development Policy (ITDP), the HealthLine had the greatest transit-oriented development (TOD) impact of any North American surface transit system per dollar of investment (2013).

**Applicability to Wake County**

The HealthLine, until recently, was the closest United States example of a Gold Standard BRT line. It has been operating for almost ten years and shows how an investment in BRT can stimulate and support economic development.

---

1 Average speeds for Full BRT and BRT Lite were calculated by dividing the route length by end-to-end travel times, which were obtained from posted schedules. Average speeds in busways were gathered from official documents and Transit Cooperative Research Program reports.
Orange Line

**Metro** – Los Angeles, CA

The Metro Orange Line began operating in 2005 and spans 18 miles. The project cost $484 million, or $26.9 million per mile. State and local funds were responsible for the majority of costs. The Orange Line mostly operates in an exclusive guideway and approaches 30,000 average weekday riders. It operates with four-minute frequencies during peak periods at an average speed of 19 to 20 mph.

**Applicability to Wake County**

The Orange Line functions in a primarily suburban environment but incorporates the elements of high-level BRT, including a fixed guideway. It is an example of how high-level investments have generated significant ridership increases.

**Key Features**

- Off-board fare payment
- Physically separated right-of-way
- Transit signal priority
EmX
LTD – Eugene, OR

EmX began operating in 2007 and spans 14 miles, connecting West Eugene with the University of Oregon and the Sacred Heart Medical Center. The project cost $100 million ($7.1 million per mile), most of which came from federal funds. At peak periods, it operates every 10 minutes at an average speed of 14 mph.

**Applicability to Wake County**

Eugene is a low-density city with a major university more than a mile from downtown. The original EmX alignment has similar operating environments to the Western Boulevard corridor. It is an example of how a bus track was squeezed into a limited right-of-way, and it pioneered the concept of a dual-direction guideway.

**Key Features**

- Off-board fare payment
- Center-running alignment
- Center-aligned stations
- Dedicated right-of-way
- Transit signal priority
Swift
Community Transit
Snohomish County, WA

Swift began operating in 2009 with a 17-mile route connecting King County to Everett. The existing line cost $29.5 million, or $1.7 million per mile. It runs in Business Access/Transit Only Lanes for more than half the route, and operates 12-minute frequencies during peak hours at an average speed of 19 mph.

Applicability to Wake County
Swift is an example of how a bus lane in a heavily congested suburban environment can generate substantial travel time savings. It is one of the few systems that has fare payment machines and smart card readers at every stop/station.

Key Features
- Widely spaced stations
- Dedicated right-of-way (for long segments)
- Off-board fare payment
- Transit signal priority
ART

ABQ Ride
Albuquerque, NM

ART began operating in November 2017. More than 70% of the 14-mile corridor is in a dedicated right-of-way, with signal priority at almost all intersections. ART runs in the center of the roadway and contains center-aligned stations. By intersecting with 32 of 37 existing bus routes, ART provides travelers with a multitude of options to connect with educational institutions and other destinations within the Albuquerque region. Service operates every 7.5 minutes.\(^2\) The total cost of physical right-of-way improvements along 8.8 miles of the route was $133.7 million (or $15.2 million per mile), with $75 million from the Federal Transit Administration (FTA).

**Applicability to Wake County**

ART was chosen as a peer system because it is the first BRT system in the United States to receive a Gold Standard rating from ITDP for transitway design.

---

\(^2\) Average operating speeds were unavailable at the time of this study.
MAX
KCATA – Kansas City, MO

The MAX began operating a six-mile route in 2005 at a cost of $21 million ($3.5 million per mile). Federal and local funds accounted for 80% and 20% of the cost, respectively. A second line spanning 13 miles (Troost Avenue) opened in 2011 at a cost of $30 million, or $2.3 million per mile. MAX operates almost exclusively in mixed-traffic, with 10-minute frequencies during peak periods at an average speed of 11 mph. MAX vehicles continue in non-BRT corridors, eliminating the need for transfers to and from feeder services.

Applicability to Wake County

MAX is an example of how BRT can be implemented with lower capital investments. The resultant ridership, travel time savings, and economic development (only $5.2 million invested in TOD) show potential outcomes with lower capital investments.
The 10-mile A Line BRT route opened in 2016 at a cost of $27 million, or $2.7 million per mile. Federal funds accounted for $7 million of the total cost, while the State of Minnesota provided $16 million in bonds and general funds. The service runs in mixed-traffic and operates with 10-minute frequencies during peak periods at an average speed of 15 mph.

Applicability to Wake County
The A Line is another example of a low-cost implementation of BRT. While it is too early to measure economic development impacts, ridership and travel time savings are instructive.
South Miami-Dade Busway

Built on an abandoned railroad right-of-way and spanning 8.3 miles, the South Miami-Dade Busway began operating in 1997 at a cost of $59 million, or $7.1 million per mile. Peak frequencies for each of the five routes operating in the busway range from seven to 45 minutes. Buses travel at an average speed of 40 mph in the busway.

This alignment is adjacent to the heavily congested U.S. 1 corridor, which connects Miami and Key West. The busway provides a dedicated right-of-way for multiple existing bus routes that allows buses to bypass congestion. Six local and limited-stop bus routes currently operate in the busway.

Applicability to Wake County

Similar to the potential infrastructure improvements proposed on Capital Boulevard, the South Miami-Dade Busway allows multiple bus routes to bypass congested areas to access the rail system.

Key Features

- Dedicated right-of-way (for long segments)
- Distinct bus stops
- Transit signal priority
Pittsburgh Busways

Port Authority
Pittsburgh, PA

The first of four Pittsburgh busways opened in 1977, spanning 4.3 miles. Three additional busways have opened since 1977, for a total length of 18.4 miles. Peak frequencies for routes operating in the busways range from four to 12 minutes, with an average speed of 30 to 40 mph. Given the connections established between downtown Pittsburgh and surrounding suburban neighborhoods, the busways are known to connect people within walking distance to their homes and jobs (ITDP, 2013). Total construction costs for all four busways was approximately $478 million, or $26 million per mile. Operations in the busway are similar to existing on-street bus operations.

Applicability to Wake County

The Pittsburgh Busways allow multiple bus routes to funnel access to downtown Pittsburgh and travel through congested areas without incurring delays. This is very similar to the infrastructure improvements proposed on Capital Boulevard.
3 Core BRT Elements

BRT systems incorporate multiple features to make bus service more appealing to riders, including branding, passenger information, and upgraded stop facilities. A summary of each peer system’s station, service planning, access, and branding attributes are shown in the Appendix.

Another key feature of BRT is improved travel times over existing bus service. Four primary elements that systems can incorporate to reduce travel times and improve route reliability include:

- **A dedicated right-of-way**, allowing buses to avoid delays experienced in mixed-traffic environments,
- **Center alignments**, allowing buses to avoid busy curbside activity,
- **Off-board fare payments**, which eliminate delays associated with on-board fare collection and allow for all-door boarding, and
- **Signal priority at intersections** to speed buses through intersections.

The systems reviewed in this study have incorporated at least two of the four factors for all or some of the BRT corridor (Figure 1). The HealthLine, EmX, and ART incorporate all four elements in their systems.
### Core BRT Elements by Peer System

<table>
<thead>
<tr>
<th>Peer System</th>
<th>BRT Type</th>
<th>Dedicated Right-of-Way</th>
<th>Center Alignment</th>
<th>Off-Board Fare Payment</th>
<th>Signal Priority at Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RTA HealthLine</strong> (Cleveland, OH)</td>
<td>Full</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Metro Orange Line</strong> (Los Angeles, CA)</td>
<td>Full</td>
<td>●</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>LTD EmX</strong> (Eugene, OR)</td>
<td>Full</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Swift BRT</strong> (Snohomish County, WA)</td>
<td>Full</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Albuquerque Rapid Transit</strong> (Albuquerque, NM)</td>
<td>Full</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>KCATA MAX</strong> (Kansas City, MO)</td>
<td>Lite</td>
<td>●</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Metro A Line</strong> (Minneapolis, MN)</td>
<td>Lite</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>South Miami-Dade Busway</strong> (Miami-Dade County, FL)</td>
<td>Busway</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td><strong>Pittsburgh Busways</strong> (Pittsburgh, PA)</td>
<td>Busway</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
</tr>
</tbody>
</table>
DEDICATED RIGHT-OF-WAY

Dedicated rights-of-way have consistently improved transit travel times. Reported travel time reductions from dedicated rights-of-way range from 25% to 50% (FTA, 2004). Research has shown that congestion delays decrease with increased running way segregation (TCRP, 2007).

There are two types of dedicated rights-of-way: grade-separated and exclusive. In a grade-separated right of way, BRT operates separately from automobile traffic, often in a former railroad right-of-way. The Pittsburgh Busways, South-Miami Dade Busway, and Orange Line in Los Angeles run along grade-separated rights-of-way for all or most of their routes (Figure 2). Research suggests that grade-separated rights of way experience approximately 40% higher operating speeds than exclusive bus lanes that are not grade-separated (TCRP, 2013). BRT along grade-separated rights-of-way generally travels between 17 to 30 miles per hour, while arterial BRT in mixed-flow traffic or designated lanes travels between 12 to 17 miles per hour (FTA, 2004).

An exclusive bus lane runs in the center of the roadway or in a curb lane. Exclusive lanes can be separated from general traffic using physical barriers (e.g. curbs) or through striping. In some cases, bus lanes can also be shared with emergency and service vehicles. As seen with Swift in Snohomish County and the MAX in Kansas City, bus lanes may be designated for bus-only use during peak periods and be available to other users during off-peak periods. All peer systems except the Metro A Line in Minneapolis run on a dedicated right-of-way for a portion of the route.

Curb conflicts due to loading, parking, right-turns, and various other uses are a key issue for curb-running systems. If conflicts do occur, and traffic flow allows, bus operators temporarily leave the curb lane to bypass the obstruction. However, delays to buses occur when this maneuver is not possible.

Figure 2     Grade-Separated Pittsburgh Busway

Source: Streetsblog USA
CENTER-RUNNING ALIGNMENT

Research suggests that median arterial busways can result in an average travel time savings of 8% when compared with a curbside bus lane running 10 miles per hour (TCRP, 2007). Center-running alignments minimize conflicts with right-turning vehicles when compared with curb-running alignments. Center alignments also avoid conflicts with vehicles accessing the curb for various uses, which is an issue that tends to hamper speeds in curb-running alignments. The HealthLine in Cleveland runs in the center of the roadway for part of its route. EmX and ART also have center-running alignments (Figure 3).

Left-turn conflicts are a common concern with center-running alignments. These conflicts are typically addressed by allowing left turns only at signalized intersections with the use of a left-turn lane and a fully protected left-turn phase. However, if left-turn volumes are low, completely prohibiting left-turns may be more desirable. Neighborhood opposition to restrict left-turns on a proposed BRT on Ashland Avenue in Chicago caused this effort to be delayed and resulted in design modifications.

Figure 3  EmX BRT with Center Alignment
OFF-BOARD FARE PAYMENT

Off-board fare payment plays a major role in reducing travel times by allowing customers to pay their fares before boarding. Travel time savings are two-fold. First, delays are minimized since bus operators no longer need to collect fares upon entry. Second, off-board fare payment allows all-door boarding to take place, further reducing delays that occur when passengers are only permitted to board from the front-most door. A series of case studies revealed that off-board fare payment resulted in a 38% to 50% reduction of passenger dwell times and in one case, a travel time reduction of up to 8% (NACTO, 2017). This metric is based on the existence of all-door boarding. Allowing boarding to occur solely at the front door would reduce travel time savings up to 50%, especially at heavy ridership stops.

All peer systems except MAX in Kansas City, buses running along the South Miami-Dade Busway, and buses on the Pittsburgh Busways employ off-board fare payment technology. Swift in Snohomish County uses a modified parking meter that accepts cash and credit for fare payment. This is an inexpensive way to have off-board fare payment options at every stop, as parking meters are less expensive and cheaper to operate than a traditional ticket vending machine.

Figure 4 Off-Board Fare Payment for Swift

Source: Oran Viriyincy, Seattle Transit Blog
SIGNAL PRIORITY AT INTERSECTIONS

Transit signal priority (TSP) facilitates the movement of transit vehicles by changing the signal to green or by extending the green signal until the bus passes through the intersection. TSP is often implemented in conjunction with exclusive bus lanes and can significantly reduce travel times. **TSP has been shown to improve travel times by 5 to 18% (TCRP, 2007).** The level of travel time improvements is dependent on multiple factors, including signal timing and conflicts with vehicles turning at intersections. Intersections operating at or over capacity will have marginal travel time savings. However, intersections that operate under capacity can experience considerable reductions in travel times through TSP. In addition, TSP’s effectiveness is enhanced by dedicated lanes at intersections.

All peer systems have incorporated TSP at some or most intersections, with the exception of buses along the South Miami-Dade Busway. TSP is illustrated in Figure 5.

Figure 5   Transit Signal Priority
4 Key Benefits of BRT

Capital investment levels in BRT vary by peer agency. The resultant benefits of the investments, as measured by travel time reductions, ridership increases, and economic development, also vary.

This chapter discusses the benefits of BRT investments and the core BRT elements that may have been contributing factors. The goal of this chapter is to help set expectations of what could be possible in Wake County.

TRAVEL TIME SAVINGS

Significant travel time savings are one of the trademark outcomes of a BRT system. Research shows that off-board fare collection, physically-separated guideways, and intersection treatments (e.g. TSP) are the biggest contributing factors to travel time savings. In addition, the increasing the spacing between stops (i.e. having stops every mile instead of 0.2 miles, as commonly seen in traditional bus service), also plays a significant role in travel time reductions. The travel time savings experienced by peer systems, described below, are examples of what could be possible with similar investments in Wake County.

**Pittsburgh Busways** experienced the most improvement (44%) among the peer systems, with time savings of over 20 minutes for the East and West Busways. As noted in a Transit Cooperative Research Program (TCRP) report (2004), time savings were attributed to the dedicated rights-of-way. There are six stops along a 5.1 mile segment in the West Busway, which allows buses to operate at speeds up to 50 mph.

The **Orange Line** in Los Angeles experienced a 31% improvement in travel time, from 72 to 50 minutes. This improvement was attributed to TSP, having a dedicated right-of-way, and reduced stop spacing. There are 18 stations in 18 miles, which amounts to an average station spacing of one station per mile.

An onboard survey conducted on the Orange Line by the National Bus Rapid Transit Institute (NBRTI) showed that a majority (71.3%) of respondents experienced a reduction in travel time. Of those 71.3%, 43% reported a savings of 15 minutes or more (FTA, 2011).

Travel times were predicted to be faster, but LA Metro reduced speed limits at intersections from 25 mph to 10 mph to reduce accidents occurring from motorists running red lights at busway intersections. LA Metro is currently studying the effects of crossing gates and/or grade separations along the Orange Line to move buses through intersections more quickly to increase speeds and travel time.

The **HealthLine** in Cleveland experienced a 30% improvement in travel time (from 40 to 28 minutes) for end-to-end travel (RTA, 2012). This improvement was attributed to off-board fare collection and a dedicated center-running alignment (ITDP, 2013). Station spacing is dense, with 59 stations in a 6.8-mile corridor.

The **MAX** in Kansas City saw a 25% reduction in travel time, from 24 to 17 minutes. The majority of this travel time reduction was due to increased stop spacing from local service. TSP also contributed to this reduction.
Swift in Snohomish County experienced a 20% reduction in travel time from pre-BRT implementation to post-implementation (Community Transit, 2017a). Station spacing averages approximately one station per mile. TSP, along with dedicated curb lanes and designated Business Access Transit (BAT) lanes, allows Swift to bypass intersection queues, which improves travel times.

The Franklin Line of EmX in Eugene experienced a small reduction in travel time (4%) from end-to-end. While this change may seem insignificant, the corridor is only four miles long. Survey results showed that over 80% of users perceived the service to be faster than the previous service. Almost half of the respondents indicated that service was at least 15 minutes faster, despite the reported 4% reduction in travel time. The decrease in travel times was attributed to reductions in signal delay, dwell time, and time spent in transit, all of which are byproducts of TSP, off-board fare collection, and having a dedicated right-of-way (FTA, 2009).

South Miami-Dade Busway experienced modest improvements (less than 10%) in travel time from pre-busway implementation. Miami-Dade Transit reduced the speed limits at intersections on the busway from 45 mph to 15 mph and deactivated loop detectors (installed for signal priority) due to busway/arterial intersection accidents. While this reduced collisions, the travel time for bus passengers increased. One safety study found that crashes were seven times more likely to occur when the loop detectors were enabled than when they were deactivated. Many other crashes were a result of motor vehicles turning right on a red light (NBRTI, 2003c).

**RIDERSHIP GROWTH**

Ridership growth is inextricably linked with travel time savings and improvements to service frequency. These level of service improvements were found to increase ridership between nine and 20% on BRT services in Los Angeles, Vancouver, and Boston. In addition, research indicates that strategies to improve customer perception and experience on BRT beyond travel time savings can increase ridership by up to 25% if implemented together (TCRP, 2007). These strategies include:

- A clearly identifiable running way that appears permanent
- Enhanced stations with unique shelter designs, lighting, intercoms, climate-controlled waiting areas, and other passenger amenities
- Uniquely designed vehicles, wide multi-door boarding, and level boarding
- All-day service span, service at least every 10 minutes, simple service pattern, and off-board fare payment
- Electronic arrival information at stops and onboard vehicles
- Branded vehicles, stations, and printed schedule information

When the majority of the strategies above are implemented together, ridership increases are most prominent due to the synergy between BRT components that provide an elevated customer experience (i.e. the whole is greater than the sum of its parts). Choosing to implement a select few strategies will result in lower ridership increases per dollar spent.

Increased time savings, in conjunction with other service improvements that accompany BRT, attracts more riders, resulting in the ridership growth that peer systems have experienced. Research has also shown that BRT can increase corridor ridership and attract new riders (NBRTI,
2003a). Ridership tends to increase as bus services become more efficient, reliable, and convenient. Where available, ridership statistics are provided below.

Between 1997 and 2004, boardings for routes running along the South Miami-Dade Busway increased by 71% on weekdays and 130% on weekends (NRBTI, 2003c).

The HealthLine experienced a 60% increase in annual ridership from its opening date in 2008 to 2014. The service has seen over 14,000 new weekly riders (RTA, 2012).

The Orange Line in Los Angeles and EmX in Eugene exceeded ridership projections. The Orange Line achieved its projected daily ridership for 2020 (20,000 passengers/day) in the first seven months of service (FTA, 2011), which represents an approximate 50% increase in corridor ridership. A ridership survey conducted three months after the Orange Line’s opening showed that 20% of riders had previously traveled by car (EDR Group, 2012). Similarly, EmX exceeded the 20-year prediction within four months of operation (NHCRP, 2009) and experienced a 50% increase in ridership during its first year of service (FTA, 2010).

MAX in Kansas City saw a 50% increase in ridership over the previous standard bus service in the Main Street corridor (NBRTI, 2009). In 2012, KCATA permitted the use of valid University of Missouri-Kansas City (UMKC) student IDs to ride MAX service, and data showed that UMKC students were making more than 1,000 trips every weekday, with the majority of these trips occurring on MAX lines (Missouri, 2013).

Swift experienced a 20% increase in ridership from previous corridor ridership during its first 18 months. The remaining Community Transit network experienced ridership declines during this period.

**ECONOMIC DEVELOPMENT**

Most of the peer systems have experienced a substantial amount of economic development along corridors and near station areas. It should be noted that the metrics used to evaluate economic development and the factors attributable to BRT vary among cities. While it may serve as a catalyst in some instances, BRT alone is not responsible for economic development. Development along BRT corridors is often guided by a comprehensive or local area plan.

RTA’s HealthLine in Cleveland spurred $6.3 billion in economic development, which includes TOD, business expansion, and the growth of major institutions (RTA, 2012). Cleveland’s citywide comprehensive plan directs development to the BRT corridor, which has certainly spurred development in the area (ITDP, 2013).

The Orange Line in Los Angeles will connect residents and visitors to at least $3 billion worth of development, 4,000 residential units, and 1.1 million square feet of office space around the Warner Center Station. This development is currently under construction. While other Orange Line Stations have been identified for potential development by Metro and other governing agencies, development at these stations has been stagnant due to a lack of community support.

The Martin Luther King Jr. East Busway in Pittsburgh experienced $903 million in TOD investment. Almost all of the TOD investments are concentrated at the East Liberty station, where development was stimulated by considerable public and private sector efforts. Development at this station only began once the government vocalized support. The West and
South Busways experienced weak TOD impacts due to limited land development potential and weak government support. Both busways mostly operate in a submerged former freight rail channel, where surrounding land is difficult to develop due to parcel size, topography, or environmental contamination (ITDP, 2013).

In Albuquerque, a pre-implementation study by the Mid-Region Council of Governments (MRCOG) revealed that an additional 150,000 residents would have transit access within 45 minutes of the University of New Mexico and Nob Hill areas because of ART. Another finding showed that a rider could access 50,000 more jobs with the implementation of ART (MRCOG, 2015). The city revised land use codes along the corridor and removed minimum parking requirements to allow mixed-use development. As a result, over $300 million in mixed-use development is planned for the corridor.

Approximately $100 million in development has been channeled along EmX corridors in Eugene. This may be due to the system’s inclusion in the Eugene-Springfield Metropolitan Area General Plan, which emphasizes mixed-use and high-density development around transit stations. Most of the development has occurred near the University of Oregon campus. The development caters to the student population in the form of hotels and apartment buildings (ITDP, 2013).

MAX in Kansas City has seen $5.2 million in TOD investments. The Main Street MAX line runs mostly through downtown Kansas City, which has experienced an onslaught of new development within the last decade. These efforts are primarily due to the emerging appeal of Kansas City’s downtown land market and a strong government push encouraging downtown development (ITDP, 2013).

In an analysis of development near the South Miami-Dade Busway, researchers found that the Busway was associated with “substantially improved economic development” when compared to the central county (Nelson et al., 2015). Results showed that economic development may not have occurred without the existence of the Busway. It appears that the Busway facilitated development in areas where access to employment centers improved and where there were opportunities for redevelopment.
REFERENCES


# Appendix

## Core BRT Elements and Benefits

<table>
<thead>
<tr>
<th>BRT System</th>
<th>Project Objective</th>
<th>Core BRT Elements</th>
<th>Benefits</th>
<th>Ridership Results</th>
</tr>
</thead>
</table>
| **RTA Healthline**  
7.1 miles  
Construction Year: 2004  
The Healthline was built to connect the two largest regional employment areas in Cleveland, provide more travel choices, support redevelopment efforts, and reduce congestion. |  
- Dedicated Right-of-Way (physical separation)  
- Center alignment (preferred)  
- Off-board fare payment  
- Signal priority at intersections  
- Center-aligned bus stations |  
- Travel time savings  
- Economic development benefits  
- Ridership results |  
- Spurred $6.3B in economic development (includes TOD, business expansion, and growth of major institutions) |  
- Annual ridership increased by 60% from opening (2008) to 2014 (RTA)  
- Over 14,000 new weekly riders |
| **Metro Orange Line**  
(Los Angeles, CA)  
18 miles  
Construction Year: 2002  
The Orange Line was built to provide rapid transit service to the San Fernando Valley from North Hollywood, at the terminus of a subway line that connects to downtown Los Angeles. It was also built to address congestion on Highway 101 and throughout the San Fernando Valley. |  
- Dedicated Right-of-Way (physical separation)  
- Center alignment (preferred)  
- Off-board fare payment  
- Signal priority at intersections  
- Center-aligned bus stations |  
- Travel time savings  
- Economic development benefits  
- Ridership results |  
- Improved end-to-end travel by 11% from previous bus route, from 72 minutes to 50 minutes (AASHTO 2012 Case Study) |  
- Thousands of residential units  
- At least 1.5M sq ft of retail  
- Warner Center (under construction): 53B development, with 4,000 residential units and 1.1M sq ft of office space  
- $300M in TOD investment (ITDP Development Study, 2013) |  
- Achieved projected 2020 daily ridership (20,000 passengers/day) in first seven months of service (USDOT/FTA Study, 2010) |
| **LTD EmX**  
(Eugene, OR)  
14 miles  
Construction Year: 2006  
Eugene was experiencing population growth, but did not have the travel demand or high enough population growth to warrant a light rail system. EmX was built along the Franklin corridor to reduce congestion. |  
- Dedicated Right-of-Way (physical separation)  
- Center alignment (preferred)  
- Off-board fare payment  
- Signal priority at intersections  
- Center-aligned bus stations |  
- Travel time savings  
- Economic development benefits  
- Ridership results |  
- Four percent reduction in end-to-end travel time (BRT Project Evaluation, 2009) |  
- 10% job growth within 0.25 miles of station (2013 case study in Journal of Public Transportation)  
- $100M in development investment in BRT corridor (ITDP Development Study, 2013) |  
- 50% increase during first year of service (2010 USDOT/FTA Study)  
- Exceeded the 20-year prediction within four months (NHCRP, 2009) |
<table>
<thead>
<tr>
<th>BRT System</th>
<th>Project Objective</th>
<th>Core BRT Elements</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community Transit Swift BRT (Snohomish County, WA)</td>
<td>Swift replaced local service operated by two separate transit agencies and eliminated a transfer at the Everett city boundary. Projected growth along SR-99 corridor suggested a growing need for transit services between Snohomish County and Everett.</td>
<td>Dedicated Right-of-Way (physical separation)</td>
<td>Travel time savings of close to 20% from 74 minutes pre-Swift BRT to 54 minutes post-implementation (PSRC Funding Application, 2017)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center alignment (preferred)</td>
<td>Information unavailable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Off-board fare payment</td>
<td>- Increased 20% above previous corridor ridership in first 18 months (Trimet Peer Review, 2015)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Signal priority at intersections</td>
<td>- Over $300M mixed-use development planned for corridor (Streetsblog USA, 2017)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center-aligned bus stations</td>
<td>- Additional 150K residents can access Univ. New Mexico and Nob Hill areas within 45 min because of ART (MRCOG study, 2015)</td>
</tr>
<tr>
<td>Albuquerque Rapid Transit (ART) (Albuquerque, NM)</td>
<td>ART was built to provide more convenient and efficient transit access to job centers along Central Avenue, a key east-west roadway. Central Avenue connects residential developments to the region’s major employment and activity centers. The city aimed to catalyze economic development along the corridor through BRT.</td>
<td>72% of corridor has dedicated ROW</td>
<td>Projected 15% improvement (ITDP, 2017)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15 of 19 stations)</td>
<td>Information unavailable</td>
</tr>
<tr>
<td>KCATA MAX (BRT Lite) (Kansas City, MO)</td>
<td>The MAX line was built to improve mobility along a busy corridor and to improve access to employment and educational opportunities for transit-dependent populations. It was intended to attract new investments to the corridor, where household poverty rates are between 21 to 35% higher than the city rate of 14%.</td>
<td>(During peak periods only in Midtown, full-time “Bus Only” in downtown, not physically separated)</td>
<td>25% improvement in travel time (from 24 to 17 min) (NBRTI, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- New development along corridor was largely driven by institutions (i.e. UMKC, Rockhurst University, Truman Medical Center) West Broadway Transit Study, 2015)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- $5.2M in TDM investment (ITDP Development Study, 2013)</td>
</tr>
<tr>
<td>Metro A Line (BRT Lite) (Minneapolis, MN)</td>
<td>The A Line was built to provide a connection between two existing light rail stations and other destinations, as well as faster and more frequent service along a busy corridor.</td>
<td></td>
<td>Projected 20% improvement in travel time (Minneapolis Post, 2016)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Information unavailable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Projected 100% increase by 2030 (Minneapolis Post, 2016)</td>
</tr>
</tbody>
</table>
### BRT System

<table>
<thead>
<tr>
<th>BRT System</th>
<th>Project Objective</th>
<th>Core BRT Elements</th>
<th>Benefits</th>
<th>Ridership results</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Miami-Dade Busway</td>
<td>The South Miami-Dade Busway was built to ease traffic congestion along the US 1 highway, and was intended to provide faster travel choices for Miami-Dade Transit customers. Studies projected population growth and increases in automobile usage with no plan to increase roadway capacity, thus highlighting a need for transit improvements such as the Busway.</td>
<td>Dedicated Right-of-Way (physical separation): ●</td>
<td>Modest improvements (TCRP Report 90, NBRTI study)</td>
<td>Between 1997 and 2004, boardings increased by 71% on weekdays and 130% on weekends (NBRTI, 2003)</td>
</tr>
<tr>
<td>(Miami-Dade County, FL)</td>
<td></td>
<td>Center alignment (preferred): ●</td>
<td>Economic development benefits: ●</td>
<td></td>
</tr>
<tr>
<td>19.8 miles</td>
<td></td>
<td>Off-board fare payment: ●</td>
<td>juvenices: ●</td>
<td></td>
</tr>
<tr>
<td>Initial Construction Year: 1997</td>
<td></td>
<td>Signal priority at intersections: ●</td>
<td>juvenices: ●</td>
<td>juvenices: ●</td>
</tr>
<tr>
<td>Pittsburgh Busways</td>
<td>The Busways were seen as an economical method of improving transit service to downtown Pittsburgh while preserving rights-of-way. The South Busway was built to enable passengers to bypass severe traffic congestion along a major roadway. Existing buses were having difficulty operating on local streets because of hilly terrain. The East Busway was developed to alleviate commuter congestion and to increase capacity without widening the roadway. The West Busway was built to improve transportation connections between the airport and downtown Pittsburgh.</td>
<td>Dedicated Right-of-Way (physical separation): ●</td>
<td>44% improvement in travel time (TCRP Report 90, 2004)</td>
<td>In 1998, five routes using the Busway accounted for 45% of total ridership (TCRP Report 90, 2004)</td>
</tr>
<tr>
<td>(Pittsburgh, PA)</td>
<td></td>
<td>Center-aligned bus stations: ●</td>
<td>- 81% of developments along the East Busway occurred within a six-minute walk to a station. Total value of developments was $302M, $242M of which was clustered at stations (TCRP Report 90, 2004)</td>
<td></td>
</tr>
<tr>
<td>18.4 miles</td>
<td></td>
<td>(Along at least 2 of 4 busways)</td>
<td>- MLK East Busway experienced $903M in TOD investment (ITDP Development Study, 2013)</td>
<td></td>
</tr>
<tr>
<td>Construction Year: varies by corridor</td>
<td></td>
<td>juvenices: ●</td>
<td>juvenices: ●</td>
<td>juvenices: ●</td>
</tr>
</tbody>
</table>
### OTHER BRT ELEMENTS

<table>
<thead>
<tr>
<th>BRT System</th>
<th>Service Planning</th>
<th>Stations</th>
<th>Communications</th>
<th>Access and Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTA HealthLine (Cleveland, OH)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Metro Orange Line (Los Angeles, CA)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>LTD EmX (Eugene, OR)</td>
<td>●</td>
<td>●</td>
<td>◆</td>
<td>●</td>
</tr>
<tr>
<td>Community Transit Swift BRT (Snohomish County, WA)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Albuquerque Rapid Transit (ART) (Albuquerque, NM)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>KCATA MAX (BRT Lite) (Kansas City, MO)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

- **Express, Limited, and Local Services**
- **Late-night service (at least until midnight)**
- **Weekend service (both Saturday and Sunday)**
- **Multiple BRT corridors intersect to form a network**
- **Underlying local service along the BRT corridor**
- **Level boarding platforms**
- **Weather-protected**
- **Safe (well-lit, transparent, security guards or cameras)**
- **At least three doors (articulated buses) or two wide doors**
- **All-door boarding**
- **Average stop spacing (miles)**
- **Branding**
- **Real-time passenger information**
- **ADA-compliant**
- **Bicycle parking/rack at stations**
- **Bicycle lanes on or parallel to entire corridor**
<table>
<thead>
<tr>
<th>BRT System</th>
<th>Service Planning</th>
<th>Stations</th>
<th>Communications</th>
<th>Access and Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro A Line (BRT Lite) (Minneapolis, MN)</td>
<td>Express, Limited, and Local Services</td>
<td>Level boarding platforms</td>
<td>Safety</td>
<td>ADA-compliant</td>
</tr>
<tr>
<td></td>
<td>Late-night service (at least until midnight)</td>
<td>Weather-protected</td>
<td>(well-lit, transparent, security guards or cameras)</td>
<td>Bicycle parking/rack s at stations</td>
</tr>
<tr>
<td></td>
<td>Weekend service (both Saturday and Sunday)</td>
<td>At least three doors (articulated buses) or two wide doors</td>
<td>Average stop spacing (miles)</td>
<td>Bicycle lanes on or parallel to entire corridor</td>
</tr>
<tr>
<td></td>
<td>Multiple BRT corridors intersect to form a network</td>
<td>All-door boarding</td>
<td>Real-time passenger information</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Underlying local service along the BRT corridor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Miami-Dade Busway (Miami-Dade County, FL)</td>
<td>Express, Limited, and Local Services</td>
<td>Level boarding platforms</td>
<td>Safety</td>
<td>ADA-compliant</td>
</tr>
<tr>
<td></td>
<td>Late-night service (at least until midnight)</td>
<td>Weather-protected</td>
<td>(well-lit, transparent, security guards or cameras)</td>
<td>Bicycle parking/rack s at stations</td>
</tr>
<tr>
<td></td>
<td>Weekend service (both Saturday and Sunday)</td>
<td>At least three doors (articulated buses) or two wide doors</td>
<td>Average stop spacing (miles)</td>
<td>Bicycle lanes on or parallel to entire corridor</td>
</tr>
<tr>
<td></td>
<td>Multiple BRT corridors intersect to form a network</td>
<td>All-door boarding</td>
<td>Real-time passenger information</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Underlying local service along the BRT corridor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pittsburgh Busways (Pittsburgh, PA)</td>
<td>Express, Limited, and Local Services</td>
<td>Level boarding platforms</td>
<td>Safety</td>
<td>ADA-compliant</td>
</tr>
<tr>
<td></td>
<td>Late-night service (at least until midnight)</td>
<td>Weather-protected</td>
<td>(well-lit, transparent, security guards or cameras)</td>
<td>Bicycle parking/rack s at stations</td>
</tr>
<tr>
<td></td>
<td>Weekend service (both Saturday and Sunday)</td>
<td>At least three doors (articulated buses) or two wide doors</td>
<td>Average stop spacing (miles)</td>
<td>Bicycle lanes on or parallel to entire corridor</td>
</tr>
<tr>
<td></td>
<td>Multiple BRT corridors intersect to form a network</td>
<td>All-door boarding</td>
<td>Real-time passenger information</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Underlying local service along the BRT corridor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>