All Aboard: Bus Rapid Transit in Milwaukee

Technical Report
BRT Overview
Route Analysis: East-West Wisconsin Avenue Corridor

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Executive Summary

It is finally on the table. Bus rapid transit (BRT) is a politically viable public transit service in Milwaukee. For the first time in the better part of half a century, a cross-sectoral group of stakeholders has gathered recognizing the legitimacy and importance of a BRT system in the city. That makes this technical report timely.

Throughout the fall and early winter of 2015, students in the School of Architecture and Urban Planning at the University of Wisconsin-Milwaukee conducted an analysis of BRT’s potential in the region, as well as a refined analysis of potential routes. Specifically, the students focused on the East-West Wisconsin Avenue Corridor – connecting Downtown Milwaukee to the Milwaukee Regional Medical Center.

What is BRT?
BRT is a high-quality bus service that delivers fast, comfortable, and cost-effective transportation service at the regional level. It is differentiated from regular bus service through five essential elements which more closely align it with light rail service, including a dedicated right of way, busway alignment, off-board fare collection, platform-level boarding, and intersection treatments. Each of these elements, plus others that we feel are essential for developing a modern rapid transit system, are explored in this report.

East-West Wisconsin Avenue Corridor
The East-West Wisconsin Avenue Corridor is of specific focus because of existing high-public transit ridership and its connection to southeastern Wisconsin’s two largest employment hubs: Downtown Milwaukee and the Milwaukee Regional Medical Center. Some consider it to be the spine of any potentially successful, future rapid transit system. This report argues that the BRT route should run through this corridor because:

1. Research shows that successful BRT systems connect major, regional employment centers: Downtown and the Medical Center;
2. Providing faster access to these major job centers is the most effective way to create mode shift;
3. The use of Wisconsin Avenue allows other Milwaukee County Transit System routes to utilize the infrastructure;
4. There is potential funding available because of the I-94 reconstruction; and,
5. Previous BRT analyses have explored this corridor.

Analysis Results for an East-West Wisconsin Avenue BRT Corridor
The UW-Milwaukee team conducted a detailed analysis of the corridor to determine the viability of a median-based or curbside BRT route. The team examined the route from four perspectives: engineering, station and corridor design, management and economics, and planning and equity. A median-based route is the preferred alternative supported by the following results:

- 36-40 minute travel time down the corridor
- 10 minute headways at each stop
- 29,568 transit riders
- $47.71 million implementation cost
- $54.3 million annual time impact savings
- $10.5 million annual safety impact savings
- 758 direct/indirect jobs potentially created
- $3.5 billion potentially leveraged in transit oriented development

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1 Institution for Transportation and Development policy: https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt/
PART I: BRT Overview

Purpose of the Report
There has been growing interest in bus rapid transit (BRT) in Milwaukee metropolitan area in recent years. In June 2015, Milwaukee County Executive directed the county transportation department to begin preliminary design work for a BRT line between downtown Milwaukee and the Regional Medical Center in Wauwatosa. More recently, in December 2015, Milwaukee Transportation Services issued a request for proposals for a feasibility analysis and conceptual design for a BRT line in the east-west corridor. Both Milwaukee Mayor Tom Barrett and Wauwatosa Mayor Kathleen Ehley have signaled their interest for BRT within this corridor.

The current interest in the east-west corridor builds on many years of planning. Indeed, SEWRPC has recommended investing in BRT or expanding express bus service in this corridor since the 1960s. A possible BRT line in the East-West this corridor is made all the more timely by the future reconstruction of Interstate 94 and the Wisconsin Department of Transportation’s desire to increase the highway’s capacity. It may be possible to dovetail the two projects in some way.

The world’s current stock of Bus Rapid Transit systems have mostly demonstrated that this increasingly popular form of public transit offers significant opportunities for high-quality development while enhancing social justice. However, thoughtful and careful planning is critical to realizing the maximum potential of BRT. It is only through mindful consideration of land use, equity, route selection and station location that these benefits are achieved. A comprehensive understanding of a region’s land use, travel behavior, and unique goals can guide planners in developing an effective and equitable Bus Rapid Transit System.

Through the observation of BRT systems already in place, both internationally and in the U.S., this report will serve as a toolbox for urban planning professionals (planners, engineers, designers, and advocates)

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in the Milwaukee region to effectively design and implement a BRT system that efficiently considers the role of dedicated bus lanes, intersection treatments, bus stations and fare collection as key indicators of a BRT system’s impact on many key concerns, including safety, travel speeds, traffic demands, and mode share.

What is BRT?
Bus Rapid Transit (BRT) is a high-quality bus service that delivers fast, comfortable, and cost-effective transportation service at the regional level. It is differentiated from regular bus service through five essential elements which more closely align it with light rail service, including a dedicated right of way, busway alignment, off-board fare collection, platform-level boarding, and intersection treatments. Each of these elements, plus others that we feel are essential for developing a modern rapid transit system, are explored in this report.

History
A few U.S. cities experimented with prototype BRT systems in the 1970s. A second wave of BRT interest occurred in the 1990s, partly spurred by the availability of new federal funding.

Today, approximately 20 U.S. cities have at least one bus line they identify as BRT, although only seven of these have enough features to be considered “true BRT,” and none of these systems have received the Institute for Transportation and Development Policy’s gold certification.

That may soon change, however; many cities across the U.S. are taking steps towards achieving gold certification, including Boston, San Francisco, Chicago. New BRT lines are also in the works for Minneapolis and Indianapolis.

Globally, BRT has nearly quadrupled between 2004 and 2014 as governments around the world turned to BRT as a cost-effective answer to many of their urban transportation needs. Today, BRT lines operate in 195 cities around the world, totalling nearly 3,250 miles.

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6 Institution for Transportation and Development Policy: https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt/
Achieving Success

One factor that drives BRT development, and defines its success is its ability to reduce travel times and create a transit option that is comparable, in time, to driving a personal vehicle. Many design and engineering elements have been shown to have significant impacts on a BRT system’s ability to achieve that goal. Analysis of 54 BRT lines suggests that average travel time improvements were 25%, but each of the common elements of a Bus Rapid Transit system plays an important role in achieving those improvements.13

Dedicated right-of-way

Buses on a true dedicated right-of-way can have running speeds of 50 mph and are not subject to normal vehicular traffic. Obtaining enough connected right-of-way to support an exclusive BRT system alignment is a significant challenge for this level of BRT infrastructure, and it may not be a practical option in all places. Therefore, many American cities have made due with a variety of alignments for bus-only lanes.

Mixed Use Lane: In a mixed use lane system, BRT shares the lane with general traffic and operates similarly to a traditional bus system. Through the use of intersection signal priority, queue-jumping and improved bus stop facilities, this type of system can see improvements from a traditional bus system.

Dedicated Lane: In comparison to mixed use lane systems, BRT systems running in a dedicated lane see significant improvements in travel speeds, travel times and reliability. In fact, Boston’s Silver Line operates with a ratio of maximum to minimum running time of 1.03, or nearly equal at times of peak traffic as it runs in low traffic. In comparison, Los Angeles’ Metro Rapid Wilshire BRT line that runs in a mixed use lane, has a ratio of 1.28.14 When considering a dedicated lane alignment, there are a few options: curbside, offset and median-based.

- Curbside and Offset Lanes: This alignment of a dedicated BRT system is on the curb side of the roadway. Based on traffic counts on the roadway and parking demands, it may be preferential to either have this system run directly on the curb edge or offset from the curb through the continued use of on-street parking. A study done for Webster Avenue in New York City showed that offset bus lane configurations, that preserve parking through the use of bus bulbouts, resulted in a projected time saving of 20%, while curbside lanes saw minimal improvement due to the occasional interruption of operation for right-turning vehicles and parked vehicles.15

- Median-based Lanes: In comparison to curbside and offset lanes, median-based lanes in the Webster Avenue study saw a projected time saving of 27% from that which would occur without

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BRT.\textsuperscript{16} Median-based lanes often require left-opening doors on the buses or criss-crossing lanes at the station, which require increased costs and may offer greater difficulty when designing the roadway.

\textit{Intersection treatments}  
A bus typically spends 10 to 20 percent of its time stuck at intersections along its route. Being able to reduce the time wasted at intersections will not only decrease the time between stops, but will also decrease the amount of wear and tear on the fleet. This would in turn reduce cost and increase income on the line.

\textbf{Transit Signal Priority:} Transit signal priority (TSP) allows an approaching bus to send a signal to a computer nearby that lets the upcoming traffic lights know that it is coming. Depending upon the timing within the phase of the signal the light will either stay green longer or interrupt the cross traffic signal timing. In Seattle the implementation of TSP has on average reduced signal delay by 57\%. Reducing the amount of times that a bus has to stop or slow down drastically reduces wear and tear on all of the systems on a bus. LADOT estimated savings in operating costs of $6.67 per bus per hour of operation.\textsuperscript{17}

\textbf{Queue Jumper Lanes:} Paired with the same technology that is used in a TSP system, this system allows the bus to pass other traffic at intersections. Queue jumper lanes cost, on average, $0.10 - $0.29 million per lane section per intersection, although they can cost a lot less if existing roadways can be repurposed.\textsuperscript{18}

\textbf{Far-side Bus Stops and Stations:} To fully take advantage of transit signal priority, far-side bus stops or stations (located just after an intersection) are preferred. On average, a savings of 4.5 – 5 seconds can be seen among bus routes that have far side stations implemented.\textsuperscript{19}

\textit{Off-board Fare Collection}  
Off-board fare collection greatly reduces passenger service times and bus dwell times. The default service and station dwell times per passenger according to the TCRP Synthesis 96 are as follows:

- Prepayment: 2.5 seconds
- Single ticket or token: 3.5 seconds
- Smart Cards: 3.5 seconds
- Exact Change: 4.0 seconds

\begin{flushleft}
\textsuperscript{16} Ibid.
\textsuperscript{17} Federal Transit Administration, “Characteristics of Bus Rapid Transit for Decision-Making,” Office of Research, Demonstration and Innovation. (February 2009).
\textsuperscript{18} Ibid.
\end{flushleft}
• Swipe or dip cards: 4.2 seconds

This makes off-board fare collection 1.5 seconds faster per passenger than exact change and one second faster per passenger than smart cards. This effect compounds with increased number of passengers and amount of stops on the route.  

**Platform Level Boarding**

Level boarding at stops is usually raised 14-15” above the existing roadway so that it is level or very nearly level with the entrance to the bus. This helps decrease dwelling time for people waiting at the bus station since they do not have to take two steps up while boarding. **Low-floor buses have been shown to reduce boarding times for ambulatory passengers to 0.2 to 0.7 of a second.** When paired with a wheelchair ramp system, boarding time for wheelchair passengers is also reduced from 46.4 seconds with a lift system, to 27.4 seconds with the ramp system. 

Platform Level Boarding has also shown an increase in the perception of service when boarding from a level platform which helps to strengthen the brand identity for people who do ride it.

**Route Selection**

When exploring a BRT system stakeholders will go about choosing the route in different ways typically depending on the goals of the project and the available budget. Thought the exact method for selecting a route varies it typically falls into two categories:

1. Connecting two major employment destinations or
2. Enhancing the service on the most heavily used route to keep up with demand.

The first strategy often results in a higher quality service with more potential for ridership increases and development along the corridor. In this case, the route is chosen to more quickly connect major regional employment centers regardless if local service exists or not, the design of the route focuses mostly on creating the fastest possible service between destinations, and selection focuses on connecting supporting land uses and areas with redevelopment potential.

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When simply enhancing existing service, ridership often maintains the same trajectory as before BRT treatments were implemented, and T.O.D or land use is not considered in route selection.

**Station Spacing**

Increasing spacing between bus stops can substantially increase travel speeds. While BRT systems that run on urban streets are not able to achieve the same average speeds as those on dedicated rights-of-way due to conflicts with other vehicles along the route and at intersections, they can still achieve some travel time savings by increasing stop spacing. The average spacing between BRT stations/stops varies from city to city in US, even in the same city. For instance (See Table-Station/Stop Spacing Time Saving), the Metro Rapid and Orange Line in Los Angles, both BRT system save 67% of the total time saving from the increased stop spacing.22

A disadvantage of bus stops spaced far apart is that walking or travel distance between destinations and stations also increases. Ridership demand needs to be considered when determining stop locations. High density population or employment areas, such as a central business district, may require more frequent stops than segments through areas with lower densities.

In general, the spacing depends on land use patterns and demographic information along the route, but stations/stops should be placed as far apart from each other as possible to improve operating speeds. Some important considerations for actual spacing includes the type of running way and passenger mode of arrival, street spacing.23

**Station Design**

The design of stations are critical to the success of BRT systems and are the most prominent icon of public transit. They are part of an important function that makes bus stops safer and visually more comfortable, while providing space for additional amenities. Additionally, station design must preserve sight lines of BRT users waiting in stations. With safety being a clear priority, the materials used and form of the station must allow for occupants to clearly see oncoming buses, but also their immediate surroundings.

Amenities in BRT stations are critical to the images of BRT:

- **Real Time Display:** Gives patrons the ability to view real time bus arrival times
- **Ticket Vending:** Time-saving mechanism for off-board fair collection
- **Enclosed/heating:** In cold weather climates, either heating or a well enclosed bus station may be necessary. Installing heat can cost between $15,000 and $75,000 extra for each shelter.24

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22 Bus Rapid Transit Practitioner’s Guide, P4-88
23 Ibid.
• Turn-stiles: Control entry to paid riders
• Bike storage: Nearby storage options enable a wider variety of patrons to utilize the bus.
• Security: Security cameras offer a sense of security for riders to increase ridership.

Branding
Branding is an essential element that defines a BRT system and helps differentiate the service from other forms of transit. A distinct design can alert the public that a new service is now available and help reset expectations about the merits of bus travel. As effective marketing campaign could potentially be the greatest asset a BRT, it is imperative that the selected branding include the right combination of a name, logo and color scheme throughout the system.

Corridor branding: Colored lanes, unique types of pavement, and eye-catching signage define the boundaries and rules of BRT lanes and create a unique path to improve the visibility of the BRT system to drivers, bicyclists, pedestrians and other travelers. Signage along the path can also direct users to nearby stations, while beautification such as landscaping can have a positive psychological impact on both users and non-users that will improve the public perception of the system.

Station Branding: Stations with bright colors, graphic designs and other eye-catching techniques will create curiosity among the public as the system rolls out, potentially increasing ridership in the future. Furthermore, users can locate branded stations more easily than simpler, non-descript designs that blend into the surroundings.

Bus Branding: The branding of BRT buses should match the corridor and station branding while also distinguishing BRT from regular city buses. Separating the BRT system buses from the local routes with not only color but also a new logo and name will further increase public awareness and the visibility of the new system to the pedestrians, bicyclists, drivers, and transit riders that happen to see a bus go by.

Potential Benefits

Investments in BRT could bring potential economic and social benefits to an area. Though many are difficult to quantify, many existing case studies existing to showcase the system’s potential effects on its surroundings.

Transit Oriented Development
Development around BRT stops is often a critical part of the systems success. This transit oriented development or TOD involves increased density and property values around mass transit stations in an urban region, and making pedestrian access easy. The high-capacity, high quality transit that BRT offers
promotes the potential of TODs based on the high accessibility and employment and economic opportunities of centering development nodes along station locations.

Relatively few reports have been produced that examine the potential that bus rapid transit has on development patterns around BRT stations. The reports that have been produced, however, assert that BRT has the ability to attract development when significant public investment has been made near transit nodes.²⁵

TOD opportunities can often be a key factor in the decision process leading up to the BRT system, as municipalities seek to leverage new investments to offset the investment in the newly established rapid transit system.²⁶ However, there are several key attributes that influence the relative success or failure of development.²⁷

These attributes in order of importance are:
- government support for TOD
- strength of the land market adjacent to the corridor, and
- the quality of the transit investment.

**Government support:** When planning a BRT systems station locations, government support for development through local zoning and land use should be one of the top considerations. It is important to review local zoning to determine what uses are permitted within walking distance of the stations. Because of the road space requirements of BRT, routes frequently go through neighborhoods which are more supportive of automobile use. In these instances, changing local zoning to be more supportive of higher density mixed use developments can provide an opportunity for economic development.

Local plans should be reviewed during the process of implementing BRT to make sure it fits the community’s vision for the area. Pittsburgh’s Baum-Centre Corridor development strategy specifically calls for transit-oriented development at three different stations along the Martin Luther King Jr. east busway. While strategically place stations can entice new development, a successful BRT system will focus primarily on connecting existing supportive land uses.

**Strength of land market:** From the research to date, the most successful BRT systems in terms of drawing transit-oriented development often connected the downtown of their respective cities to another site or sites with significant growth potential, such as a medical complex, university, or research park. Another factor noted is the potential for an increase in land values adjacent to the system.²⁸

²⁷ ITDP, 2013
²⁸ ITDP, 2013
The most successful corridors studied to date were those associated with the Cleveland Healthline and the Portland, Oregon LRT Max line. The Healthline, which connects downtown Cleveland with a major medical complex is of particular interest as a comparison to Milwaukee’s proposed east-west corridor route, which would connect downtown to the Milwaukee Regional Medical Center in Wauwatosa. Cleveland’s corridor had the highest level of TOD relative to BRT investment of any of the corridors studied.\(^{29}\)

**Quality of Transit Investment:** Lastly, successful TOD is typically associated with BRT systems that use a street shared by other forms of mass transit. In the case of Milwaukee’s Wisconsin Avenue, it currently has the largest number of bus routes currently operating on this street and the highest number of bus routes connecting to it; reference MCTS system route map. As noted above, the new Streetcar line will also intersect with this route.

**Equity**

The time-savings aspect is a key component of BRT’s equity-related success, affording those who do not have access to a personal vehicle competitive travel time to those who do. However, a recent survey of studies on BRT systems in developing nations demonstrated that the cost of BRT systems can be prohibitively expensive to those who stand to benefit most from the service – namely, those far beneath the poverty line. Additionally, the same survey found significant evidence that BRT systems can and do exacerbate levels of gentrification near stations, resulting from increased land values and higher property taxes and pushing out existing, lower-income residents.

**Safety**

More people taking BRT means fewer drivers on the road who might potentially cause traffic crashes. If BRT is in a dedicated lane, this results in fewer conflicts between buses and other drivers. In fact, Pittsburgh’s busway, through its East Corridor, was associated with a “30% reduction in all accidents.”\(^{30}\) Bus and vehicle driver behavior changes when not competing for space with the other unit, and different alignments of the busway in the right of way can have significant impacts. Considering pedestrian safety, offset BRT lanes are often advantageous to curbside or median-based systems because they reduce crossing distances with “neckdowns at intersection approaches, bus bulbs at station locations, and pedestrian refuge islands where left-turn lanes are not required.”\(^{31}\)

In comparison, curbside systems decrease pedestrian space on sidewalks because of the stations and provide no benefit to reduce crossing distances. Median-based systems often occur near signalized intersections to increase accessibility and provide refuge islands for pedestrians.

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\(^{29}\) ITDP, 2013  
\(^{30}\) Ibid.  
**Mode Shift**

Though mode shift from transit investments can be difficult to predict, bus rapid transit has been successful in other cities at encouraging a higher proportion of the population to utilize public transit as their daily transportation. This was seen in Cleveland’s Healthline, which saw new riders (who had shifted from other modes) represent 18% of BRT riders (2,800 passengers). While many studies are unable to quantify the impact of individual components of BRT on mode shift, potential influences include, faster bus travel times/speeds, greater transit reliability, reductions in parking availability and potentially higher auto travel times due to lane reduction.

**Costs**

Costs incurred during a system expansion will impact the Milwaukee County Transit System in the short and long term. Short-term capital costs will fund the creation of the system, while long-term operating costs will maintain it.

Costs to the traveling public include monetary costs associated with travel (e.g. vehicle ownership/maintenance costs, public transit fees) and time spent traveling. A competitive BRT system needs travel times similar to or faster than driving a private automobile (especially during rush hour) and reasonable user fees that the public is willing to pay.

Travel costs for BRT depend on the fare structure, which can be either flat or differentiated. A flat fare structure can result in higher overall ridership, while a differentiated fare structure (higher costs during peak periods) can result in more off-peak ridership. Differentiated fare structures also tend to see higher revenues.

**Capital Costs**

Capital costs primarily include the work associated with system design, engineering, and project management. These are one-time expenditures that do not reoccur, nor will they be included in ongoing operations and maintenance costs. Capital costs include: right-of-way acquisition, corridor and station construction, purchasing vehicles, and the installation of supporting technology (fare collection, ITS applications, passenger information).

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Funding Sources

The Milwaukee County Transit System faces substantial fiscal challenges that will make implementation of any adopted system expansions difficult. MCTS currently receives 42% of its funding from the State of Wisconsin,33 an amount which is vulnerable to substantial cuts depending on the political and economic climate.

However, federal grant programs, such as FTA Small Starts and the DOT’s TIGER (Transportation Investment Generating Economic Recovery) program could be possibilities to obtain some of the startup capital funding for a BRT system.34 Either program would still require a substantial local contribution – at least 20% of the total project cost – which remains a challenge to be solved. This may take the shape of partnering with other public or private who will benefit from the transit investment, as was done in the development of Cleveland’s Healthline BRT.35

Federal and state funding sources provide the majority of financing available for BRT system installation and improvements. The United States Department of Transportation, the Federal Transit Administration, and the Wisconsin Department of Transportation (WisDOT) offer multiple grants to offset the initial capital costs to a municipality.

New Starts Projects (through the FTA and MAP-21)
- Total project cost greater than $250 million and total New Starts funding sought equals or exceeds $75 million
- For a new fixed guideway system or extension to an existing system

Small Starts Projects (through the FTA and MAP-21)
- Total project cost less than $250 million and total New Starts funding sought is less than $75 million
- For a new fixed guideway system, extension to an existing system, or a corridor-based BRT system

TIGER Discretionary Grant Program (through U.S. DOT)
- Provides capital funding for a public transportation project directly to a public entity.

Additionally, the Milwaukee transit environment may provide a substantial ridership obstacle to overcome in order to achieve a financially sustainable system. Contrary to the rest of the United States, MCTS has been losing ridership in recent years, due mostly to a decrease in the level of service.36

35 Ibid.
Though a well-designed BRT system would be expected to achieve higher ridership levels than local bus routes, increased fare revenue alone will not solve the significant operational funding obstacles that MCTS faces. It is likely that additional funding strategies, such as a dedicated regional transit authority or county-wide wheel tax will be necessary to operate a viable transit system, including BRT, into the future. More detail is provided on pp. 55-56.

A Milwaukee Approach

Route Selection
Following route selection guidelines that focus more on the destinations rather than simply mirroring an existing route will give Milwaukee’s BRT the best redevelopment and ridership potential. Milwaukee also has the possibility to go beyond the Cleveland example by designing a corridor that can accommodate existing MCTS routes in addition to new BRT service. Using BRT to serve new areas while also creating a system that can be used by the existing routes will allow many more transit users to experience the higher quality service offered by BRT.

Based on the experiences of Cleveland, Portland and other cities evaluated, it would seem that a BRT system linking downtown Milwaukee and continuing west to the Milwaukee Regional Medical Center in Wauwatosa would seem to have good potential for TOD. Demographic and planning trends in Milwaukee show an increase in the number of people living or desiring to live in the downtown area. One could also expect continued expansion in employment both downtown and near the medical complex and the city’s continuing desire to improve the areas adjacent to Wisconsin Avenue west of the Milwaukee River.

An area of particular benefit would be the corridor adjacent to Wisconsin Avenue from the river to 12th Street (Westown neighborhood). This would include an intersect point with the new Streetcar Line planned for the downtown Milwaukee area.

Based on the experiences of other cities as noted in the references listed, the proposed BRT system along the Wisconsin Avenue route connecting downtown Milwaukee to the Froedtert Medical Complex in Wauwatosa could result in TOD well in excess of the investment dollars needed to fund the establishment of this system.

Station Spacing
Generally, stations/stops should be spaced 0.25 to 0.33 mile apart in Downtown Milwaukee, Milwaukee Regional Medical Center, UW-Milwaukee Campus and other areas passenger mainly arrive as

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37 Henken, R. Guest lecture, University of Wisconsin-Milwaukee. (2015, October 26).
38 Milwaukee Downtown Business Assoc., 2012
39 City of Milwaukee Downtown Plan, 2010
40 Milwaukee Streetcar, 2015
pedestrians, purposeful shorting space between stations/stops in these areas could provide better accessibility of the BRT facilities; 0.5 to 1 mile for stations/stops in median density neighborhoods, such as East Side and West Side neighborhoods, where passenger mainly arrive by bus or bicycle; also, the stations/stops should be spaced more than 1 mile where passengers mainly arrive by automobile, such as Brookfield and Wauwatosa suburbs. Additionally, the dwelling time should increase with the increasing stations/stops space to provide certain ease for the customers those who have to travel far distance.

Station Locations
The location of BRT stops shall be able to reflect the proximity to the major centers and high accessibility to the BRT services, especially in high population density area such as downtown core.

Generally, the typical consideration for station locations/stops would be at the major origins and destinations, and major transit transfer points. The selected location should be within 5-10 mins walking distance from the origin. For West-East Corridor in the City of Milwaukee, the stations/stops shall beproximate to pedestrian hot spot and transit transfer stations at Milwaukee Regional Medical Center, Downtown Milwaukee, etc. These nodes could provide sufficient ridership and have public demand for transit services, by locating the stations/stops at these areas could maximum the serviceable population of the BRT system. Moreover, providing easy transfer services or better accessibility for the majority of transit users.

Station Design

Similar to MCTS, users of the prospective BRT system will require sufficient shelter while waiting to board an upcoming bus. Enclosure from the elements is a priority, particularly a roof to protect users from the Midwestern climate. The stations can be either open air or an enclosed and heated space in order to provide comfort for BRT users. Downside of comfortable stations are added costs associated with more materials or the cost of running heaters through colder months. Enclosed shelters are more cost effective than heated ones in the long run due to lower maintenance and electricity costs.

A station placed in the middle of the street would allow for a singular, multi-directional station. This station could potentially serve as a larger main location stop. A singular, centrally oriented station would spatially be beneficial because it would allow for the construction of one station serving both directions of the routes (opposed to a curbside oriented corridor), which would in turn reduce the overall material, time, and labor costs of construction and implementation.

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41 TCRP, Report 118, Bus Rapid Transit Practitioner’s guide, Exhibit 4-13 Sources for BRT travel Time Savings, P4-8; APTA BTS-BRT-RP-004-10, Bus Rapid Transit Service Design, Table 1 Distances between BRT Stations
Modular design can provide Milwaukee BRT riders a sense of cohesiveness and brand identity through design, as well as make stations a visible landmark within the city’s infrastructure. A clear design language, such as the specific use of industrial, and locally identifiable materials, contribute towards integrating BRT as a valuable method of transportation throughout the city.

**Zoning for TOD**
Based on how other cities have changed zoning to be more supportive of BRT, Milwaukee has several options which have been shown to encourage Transit Oriented Development.

**Form-Based Code:** Form-based code is useful when many different types of land use are desired near the station. This technique is often favored for neighborhoods which are in need of significant investment. Because from based code does not restrict the type of land use, developers are granted with more flexibility to invest in ways that can maximize profit.

**Overlay Zoning:** Overlay districts provide an additional level of oversight compared to form-based code. While specific uses are not prohibited any development plan within the district requires pre approval. This type of control is often best for stations located in established neighborhoods with plenty of developable land but also several existing transit supportive developments.

**Incentive Zoning:** Incentive zoning is a tool best reserved for stations located in a city’s most desirable neighborhoods. Incentive zoning allows a development to exceed a neighborhoods density restrictions if it meets a pre-defined requirement. Often these requirements include a percentage of the developments residential units be “affordable” or that the development employ certain sustainable features.

Milwaukee could benefit from employing all three of these zoning techniques along new BRT corridors depending on the conditions of the individual neighborhoods where stations are located.

**Equity**
To be equitable, Milwaukee’s rapid transit must offer competitive travel times between major employment centers and region-wide attractions, while serving neighborhoods that need efficient transit. A recent study completed by the Public Policy Forum has found that BRT systems across the country have created time savings between 10 and 45 percent. If Milwaukee aims for a truly innovative rapid transit system, bus travel would be time-competitive with personal automobiles, if not faster. However, the region must aim while preventing ridership fees that are so prohibitively expensive as to exclude the residents that would otherwise rely on the service the most. A similar pricing structure to current MCTS fees should be explored.

Lastly, the City of Milwaukee should anticipate the success of the BRT system by designing Transit Oriented Development that responds to the challenges of gentrification. Equity-sensitive TOD can include inclusionary zoning, incentive zoning for affordable housing and overlays mandating affordable
housing. It should also be emphasized that public opinions, especially those of disadvantaged populations, should be collected from the earliest stage possible and throughout the planning process. Without a familiar understanding of the issues facing the populations when it comes to moving around the region, no new transit system can hope to bridge the disparities that pervade Milwaukee’s current transit system.

Local Challenges

Politically, transit investment is and always has been a hot-button issue in Milwaukee County. BRT systems have been proposed locally as far back as 2008 in many different forms, but no consensus has been able to be reached between the City of Milwaukee and Milwaukee County.\(^{42}\) Other rapid transit proposals reach back even further to 1971, but have never reached the implementation phase due to competing priorities.

Development of an effective system in Milwaukee County will require the cooperation of MCTS, operated by Milwaukee County, the City of Milwaukee, suburban communities depending on routes, local highway and public works administrations, and SEWRPC, all of whom have different long-term goals and objectives for their separate stakeholders. This problem has been documented time and time again as a significant barrier to the implementation of a strong BRT system in many cities throughout the country.\(^{43,44}\)

Depending on the timing, a BRT proposal is likely to become a major issue in the 2016 election, during which both Milwaukee Mayor Tom Barrett and Milwaukee County Executive Chris Abele are running for re-election, along with several city aldermen and county supervisors. Knowing this may affect the likelihood of attracting a “political champion” to shepherd the proposal through the approval process, something viewed as crucial on the rough road toward implementation.\(^{45}\)

\(^{42}\) Ibid


PART II: Route Analysis – East-West Wisconsin Avenue Corridor

A detailed analysis of the corridor was conducted to determine the viability of a median-based or curbside BRT route. The analysis examined the route from three perspectives: engineering, station and corridor design, and management and economics.

The East-West Wisconsin Avenue Corridor is of specific focus because of existing high-public transit ridership and its connection to southeastern Wisconsin’s two largest employment hubs: Downtown Milwaukee and the Milwaukee Regional Medical Center. Some consider it to be the spine of any potentially successful, future rapid transit system. This report argues that the BRT route should run through this corridor because:

1. Research shows that successful BRT systems connect major, regional employment centers: Downtown and the Medical Center;
2. Providing faster access to these major job centers is the most effective way to create mode shift;
3. The use of Wisconsin Avenue allows other Milwaukee County Transit System routes to utilize the infrastructure;
4. There is potential funding available because of the I-94 reconstruction; and,
5. Previous BRT analyses have explored this corridor.

1. Engineering

Through an analysis of current travel conditions in the Wisconsin Avenue corridor, this report intends to analyze the impacts of a bus rapid transit system on existing travel times, traffic loads, parking availability, safety and commute mode share, to better understand the impacts and opportunities of introducing BRT between downtown Milwaukee and the Milwaukee Regional Medical Center.

Alternatives Analysis

In attempting to specifically analyze the route potentials of this corridor, three alternatives have been developed. They are as follows:

- Alternative 1: No Build Scenario
- Alternative 2: Median-aligned BRT System
- Alternative 3: Offset Curb-aligned BRT System

Moving forward in this report, all discussion of current or existing public transit conditions in the corridor should assume that Alternative 1 (No Build Scenario) utilizes the existing MCTS Gold Line for baseline data because it is the MCTS route that operates most closely to the east-to-west corridor route studied here.

Alternative 2 (Median-aligned BRT System) assumes the use of a dedicated, median-aligned BRT lane in each direction throughout the corridor. Similarly, Alternative 3 (Offset Curb-Aligned BRT System), operates in a dedicated, curb-aligned lane for the entirety of the corridor. One key distinction to be made here is the need for separation between lanes. A median BRT system benefits from the ability to utilize physical barriers between the BRT lane and travel lane as a means of keeping non-BRT users out. An offset
curbside alternative will utilize rumble strips and roadway paint as a way of delineating lanes, but physical barriers cannot be used because other vehicles must cross the lane to access the parking lane. Street cross sections along numerous key portions of the corridor are provided in Appendix A.

For each alternative, there are 7 proposed transit stations, ranging in distance from half a mile apart to 1.75 miles apart. Station locations were chosen in response to three main concerns: 1) employment density, 2) existing high ridership numbers, and 3) right-of-way constraints.

A summary of analysis results for each alternative is provided in Table 1.2 at the end of this document. Additional travel time, traffic, parking, cost, safety and mode share analysis is discussed in the following sections of this report.

**Travel Times**
The closest existing transit route to the proposed BRT corridor is the MCTS Gold Line. The Gold Line travel times (Alt. 1) are used as a baseline for comparing travel times to the proposed alternatives (Alt. 2 and 3). The average travel times on the Gold Line currently vary depending on the time of the day and direction of travel. An average travel time through the corridor during peak hours, 6-9 am or 3-6 pm, is around 54 minutes (Appendix A.1). The proposed BRT line along the corridor will decrease transit travel time to around 36-42 minutes so that it is shorter than that of the Gold Line and the BRT travel time is competitive relative to the current automotive travel times.

Through Alternatives 2 and 3, the BRT line would be able to fulfill the goal of providing a competitive alternative form of transportation. These two alternatives will dedicate two of the four existing travel lanes to directly serve the BRT line. This alone is able to reduce travel times significantly due to the reduction in car vs. bus impacts that occur from sharing road lanes, reductions have been shown to be between 15-20% from the original travel time.

Travel times for the median based alternative are estimated to have a lower travel time through the corridor than the curbside alternative. This is because of the extra interactions, right turn lanes, vehicles parking, delivery vehicles, that do not allow for the same level of travel time reductions as the median alternative. Another feature that is proposed for both alternatives 2 and 3 is the implementation of Transit Signal Priority (TSP). Because of these features, travel times along the corridor should be able to achieve a reduction of up to 26% for the median based alternative (Alt. 2) (Appendix A.2) and a reduction of up to 19% for the curb based alternative (Alt. 3) (Appendix A.3).

**Traffic Impacts**
Between the Regional Medical Center and Downtown Milwaukee, 7,000 to 15,900 vehicles currently travel along Wisconsin Avenue each day. During peak travel periods, the corridor carries roughly 750 to 1,150 vehicles per hour in a single direction. The calculated capacity of the existing condition ranges from 1,392 vehicles per hour (west of Hawley Road) to 3,153 vehicles per hour (37th Street to 27th Street) in each direction. Capacity of the roadway for each alternative is calculated using a Federal Highway Administration procedure for urban 1, 2, or 3-lane roadways. More information can be found in Appendix A.

Alternatives 2 and 3 both propose dedicating a travel lane in each direction east of Hawley Road so that the entire corridor has a total of two mixed-use travel lanes (one in each direction) and two BRT bus-
only lanes. Alternative 3 would have slightly higher capacity (approximately 50 vehicles per hour more) than Alternative 2 in certain segments of Wisconsin Avenue where Alternative 3 has 11-foot travel lanes and Alternative 2 has 10-foot travel lanes.

All three alternatives appear to have sufficient capacity to handle the current peak travel flows. However, Alternatives 2 and 3 result in significantly less excess or unused capacity of the roadway when compared to Alternative 1. Additionally, these estimates for each segment of Wisconsin Avenue do not account for any reduction of vehicular traffic due to mode shift, so there is a potential for fewer vehicles using the roadway than otherwise expected.
Additionally, the corridor benefits from redundancy in the roadway system, particularly near Downtown Milwaukee where there are many streets running parallel to Wisconsin Avenue. The grid network allows parallel routes to carry some of the traffic burden if the corridor becomes overused. For example, Wells Street, located a block north of Wisconsin Avenue, has similar automobile capacity to Wisconsin Avenue but generally lower AADT volumes, which gives it the ability to carry more traffic than it currently does should Wisconsin Avenue begin to reach its capacity.

Parking Impacts

On-street parking is treated slightly differently under the two alternatives. Median based station placement (Alternative 2) does not have any impact on the number of on-street parking spaces. This is due to the buses and bus lanes being located in the center of the roadway, which does not interfere with on-street parking along the curb.

Curbside station placement under Alternative 3 does require the repurposing of space that is currently used for on-street parking. There are currently around 5,000 spaces open for drivers to use in the central business district or the downtown area through which Wisconsin Avenue runs, and with only 5 stations that would directly impact parking on Wisconsin Avenue there would be a loss of approximately 50 spaces altogether. Currently, only 72% of the spaces are being used during peak periods, so this 1% loss would not be a detriment to the existing parking conditions along the proposed route.

The decision was made to keep parking lanes in both Alternatives 2 and 3 in order to increase the likelihood that the alternatives would be supported by local businesses and other property owners located near the corridor. Additionally, removing an 8-foot parking lane would not provide sufficient room for an additional travel lane that generally requires 10+ feet.

Cost

The costs associated with transit is always a major deciding topic of any publicly funded project. The following costs are associated strictly with capital costs only and do not include any sort of operating costs.

Some costs are common throughout the system, and will be consistent no matter the alternative chosen:

- **Station construction**: Average of $480,000 per station, total of $5.28 million
- **Specialized buses**: $780,000 each, total of $9.39 million for 12 buses

For alternative 2, median, the infrastructure cost per mile comes out to an average of around $5.17 million for 6.4 miles which equals out to around $33.07 million. Therefore, the total cost of this alternative is estimated to be approximately $47.71 million.

For alternative 3, curbside, costs for road construction are noted to be lower than that of alternative 2 due to the fact that the existing median does not need to be touched or reconstructed. We estimated this total to be approximately $4.89 million per mile, or $31.3 million, for a total cost of $45.94 million.
The costs for the alternative 3 can be reduced if reconstruction was only limited to around where the stations are being proposed.

Alternative 1 would see the costs remaining the same as they are right now because there would be no new capital costs due to no routes being added or subtracted, and, in theory, no new roadwork. The capital costs in roadwork portion of this section include; materials, new TSP infrastructure, and other miscellaneous items.

To put these costs into perspective for Milwaukee, the capital costs for the initial 2.5 miles of the planned Milwaukee Streetcar project are $98.9 million. This works out to be $39.6 million per mile of the Phase 1 streetcar route, which is almost six times greater than the cost of either the Alternative 2 or Alternative 3 BRT systems on a per-mile basis.

**Safety**

Between 2010 and 2014, Wisconsin Avenue, the focus area of Milwaukee’s proposed east-to-west BRT system, saw a total of 1,377 crashes. Of these crashes, 453 involved injuries. Utilizing the estimated 33% reduction in total crashes and 41% reduction in injury-related crashes, Wisconsin Avenue could see a reduction of over 90 total crashes per year in the corridor and 37 injury-related crashes per year, as a result of the introduction of BRT. Utilizing the FHWA Safety Benefits Framework, this would result in a savings of over $10.5 million.

Reference Appendix A for a detailed breakdown of potential crash reductions for the Wisconsin Avenue Corridor and additional information on the safety implications of BRT as identified through the 2015 EMBARQ study.

**Figure 1.1: Changes to the Street Infrastructure to Accommodate BRT and Associated Safety Benefits**
**Mode Share**

Our final measure estimates the mode share impacts of each BRT alternative. We use the Home-Based Shopping Mode Choice Model application of the Southeastern Wisconsin Regional Planning Commission’s 2035 transportation model to estimate the probability of trips being made by transit, rather than by personal automobile. This model considers the following variables:

- person cost by mode,
- travel time (both in and out of mode vehicle), and
- availability of vehicles to the household.

It should be noted that the SEWRPC model intends to estimate mode share at the regional scale, and thus applying the model to a street segment tends to yield inaccurate estimates. However, we aim to examine the direction and the magnitude of mode share differences associated with different alternatives, and this model can begin to quantify that difference.

As a whole, BRT impacts on travel time, both in and out of vehicle, resulted in an increased probability of any particular trip being made by transit between 19% and 24% on Wisconsin Avenue. With I-94 as an option, probabilities increased only between 6% and 13%, with the higher likelihood coinciding with peak travel periods. Complete results of mode share analysis utilizing the SEWRPC home-based shopping model can be found in Appendix A.

The Van Ness Corridor Study from the San Francisco County Transportation Authority was also utilized to calculate potential ridership impacts in the corridor. Projecting this study's potential impacts on the current number of daily transit riders in the Wisconsin Avenue Corridor, our Alternative 2 (Median) would result in 7,665 new transit riders (2.6% increase in mode share) within 5 years of implementation and our Alternative 3 (Curb) would result in 6,133 new riders (1.9% increase in mode share). Ridership data was calculated within a half mile buffer of Wisconsin Avenue.

In addition, the FTA report observed the percentage of new transit riders coming from private automobile for eight U.S. and Canadian BRT systems, and determined that the average percent of new ridership that was pulled from private vehicle users was nearly 24%. Projecting this estimate on local data suggests that 1,840 new riders to a median-based alternative or 1,472 new riders to a curb-based alternative will come from private vehicles. As a result, personal vehicle mode share would decrease by 2.3% with the implementation of a median-based alternative and 2% with a curb-based system.
Table 1.1: Percentage of Ridership from Private Motor Vehicles for BRT Corridor Comparisons

<table>
<thead>
<tr>
<th>BRT Corridor</th>
<th>% of Ridership from Private Motor Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuquerque Rapid Ride</td>
<td>33%</td>
</tr>
<tr>
<td>Boston Silver Line Washington Street</td>
<td>2%</td>
</tr>
<tr>
<td>Boston Silver Line Airport</td>
<td>20%</td>
</tr>
<tr>
<td>Boston Silver Line BMIP</td>
<td>50%</td>
</tr>
<tr>
<td>Las Vegas MAX</td>
<td>10%</td>
</tr>
<tr>
<td>Los Angeles Orange Line</td>
<td>33%</td>
</tr>
<tr>
<td>Oakland San Pablo Rapid</td>
<td>19%</td>
</tr>
<tr>
<td>Halifax MetroLink (All lines)</td>
<td>26%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>24%</strong></td>
</tr>
</tbody>
</table>

**Recommendation**
We recommend Alternative 2 as the preferred alternative for the east-west corridor. This median-based BRT alternative has the greatest potential to improve transit between the Milwaukee Regional Medical Center and Downtown Milwaukee, as demonstrated by the lower transit travel times and higher transit ridership that are projected under this alternative.

While Alternative 2 does have greater impacts to automobile traffic, it retains an acceptable Level of Service throughout the corridor. Mode shift from automobile to transit use has the potential to alleviate some traffic congestion, and the existing grid network through the busier segments of the corridor can maintain traffic equilibrium if Wisconsin Avenue becomes congested during peak travel periods.

Additionally, parking impacts are minimized in Alternative 2 as parking lanes are maintained along each side of the street. The median-based alternative does have the highest capital costs, but this is offset by the increased benefits that it provides and its potential for lower operating costs. In fact, in the reduction of crashes alone, BRT is expected to result in an annual savings of $10.5 million.
Table 1.2: Alternatives Comparison

<table>
<thead>
<tr>
<th></th>
<th>Alternative 1 - No Build</th>
<th>Alternative 2 - Median-based BRT</th>
<th>Alternative 3 - Curbside BRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto Travel Time</td>
<td>30-32 minutes</td>
<td>30-32 minutes</td>
<td>30-32 minutes</td>
</tr>
<tr>
<td>Public Transit / BRT Travel Time</td>
<td>50-55 minutes*</td>
<td>36-40 minutes</td>
<td>38-42 minutes</td>
</tr>
<tr>
<td>Headways (During Peak Travel Times)</td>
<td>16 minutes</td>
<td>10 minutes</td>
<td>10 minutes**</td>
</tr>
<tr>
<td>Traffic Impacts:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume / Capacity Ratio</td>
<td>0.26 - 0.76 (LOS A to D)</td>
<td>0.57 - 0.83 (LOS C to D)</td>
<td>0.57 - 0.80 (LOS C to D)</td>
</tr>
<tr>
<td>Corridor Transit Ridership</td>
<td>21,902</td>
<td>29,568</td>
<td>28,035</td>
</tr>
<tr>
<td>Cost of Implementation</td>
<td>$0</td>
<td>$47.71 Million</td>
<td>$45.94 Million</td>
</tr>
</tbody>
</table>

**Future Work**

When developing a BRT line, a major concern is the impact that it will have on local transit routes. In choosing the median-based alternative as the preferred alternative for Milwaukee, it is suggested that all bus routes that run along Wisconsin Avenue be rerouted into the dedicated median lanes that are provided for BRT. The one exception to this would be the Gold Line, which would operate as the only local bus along Wisconsin Avenue. Since the Gold Line currently operates almost entirely from downtown to the Milwaukee Regional medical Center, it would pick up important stops from other bus routes that previously provided local service on Wisconsin Ave.
Future research should study local routes further and pursue more robust ridership studies. These could help suggest what transit mode shift is occurring between local routes and BRT, and what routes, if any should be reduced or removed.

In addition to concerns about the demand for both BRT and local bus routes, there may be concerns in the future over the capacity of the BRT system to expand in response to growing ridership. With the proposed system projected to run at 10 minute headways during peak periods, there is room to add buses to the BRT line if increased ridership demands it. Future analysis can study longer term impacts of mode share in the corridor, and determine if the roadway has the capacity to handle growth, or if increased infrastructure must be provided.

The conversation of growth and expansion is an important one for BRT. Future research must identify other key corridors for BRT implementation in the region and study how those routes can interact with this one. In addition, as BRT is developed, the discussion must be raised about the relationship that will exist between Bus Rapid Transit and the Milwaukee Streetcar. Early analysis of each system suggests similar goals for regional travel, and further analysis should be performed to quantify their benefits and impacts.

None of the proposed alternatives in this study include bicycle lanes or other bicycle facilities explicitly. Adding bicycle facilities - particularly bicycle lanes - along the corridor would detract from the already limited available right-of-way. It is recommended that bicycle lanes be placed on nearby parallel routes and not necessarily along the east-west corridor itself. Placement of bicycle lanes and other bicycle facilities should be evaluated on a city- or region-wide scale in order to provide a complete bicycle network that connects to the proposed BRT system and other transit without necessarily sharing the same roadways.

Data References


2. **Corridor and Station Design**

The design of BRT corridors, stations, and buses is essential to success. Even if the planning, engineering, and financing are all in place, a BRT system cannot function well if the needs of the users are not well-addressed. This section of the report addresses the corridor design and lane designation, the location of stations within the street right-of-way, station design, and system branding.

**Background**

While BRT and local bus service share the common element of the bus itself, BRT systems are designed to also feature dedicated lanes along the route corridor and the more substantial station designs with features like platform-level boarding, real-time displays, and ticket vending machines.

**Corridor Design**

BRT systems often include both dedicated bus-only lanes, which are separated from traffic, and mixed-flow lanes, where the buses and other vehicles share the same space. While dedicated lanes help create faster travel times, mixed-flow lanes are sometimes necessary in constrained corridors where the space for dedicated lanes is simply not available.\(^{46}\)

**Lane Designation**

A variety of different methods can be used to indicate bus-only lanes in a BRT system. The simplest and lowest-cost method is basic roadway striping using a solid white line and “BUS ONLY” pavement markings. In some cases, signage along the side of the roadway is used in addition to or in place of pavement markings, especially when the lane is only reserved for buses during peak traffic periods. However, the main disadvantage of this type of lane designation is that it is easily ignored by other drivers. When the bus-only lane is crowded with regular traffic, travel times on the system may slow significantly.\(^{47}\)

Alternative pavement colorings create a more visible separation of bus-only lanes without an actual physical barrier. Red pavement is the most common color used, and the lanes are still marked with a white line separating the lane from other traffic and “BUS ONLY” pavement markings informing drivers of the different use of the lane.\(^{48}\)

Physical deterrents like rumble strips and bollards are more expensive but also add an additional layer of separation between bus-only lanes and other traffic. While cars may still be able to enter the lane, especially if turning from an adjacent side street, such infractions are much less common than when only visual differences between the types of lanes are used. Finally, in some cases bus-only lanes are separated from other traffic by full curbs or even routed to a separate roadway altogether. The disadvantage of this level of separation is that while cars cannot enter the bus lanes, emergency or service vehicles may have difficulty accessing the lane when necessary. Also, the buses themselves are less able to exit the lane when needed, such as when they break down or simply wish to pass another bus.\(^{49}\)

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\(^{46}\) [http://nacto.org/docs/usdg/service_design_guidelines_vta.pdf](http://nacto.org/docs/usdg/service_design_guidelines_vta.pdf)


Station Location

Locating BRT stations within a roadway can become a surprisingly complex decision due to the various options and the potential effects on the broader system. First, BRT stations can be built on the sidewalk like a local bus station, which is typically called curbside, or in the road itself, which is typically called median. For curbside stations, the bus-only lane must be located directly against the curb itself, while for median stations the bus-only lanes are located in the center of the roadway.

Additionally, stations can be located before intersections, after intersections, or directly between stations at the mid-block point. Lastly, while curbside stations can only be accessed by buses with right-side doors in areas when traffic travels on the right side of the street, median stations can be designed for either buses with either right-side or left-side doors.

Curbside

- Can be easily combined with existing local bus stations
- Require less roadway space than median stations
- Pedestrians access the station directly from the sidewalk
- Adjoining sidewalk space may have more room for bike storage or other amenities
- Conflicts with right-turning cars and bicyclists using the outer lanes are more common

Median

- Require more roadway space than curbside stations
- Pedestrians access the station from the crosswalk at the nearest intersection
- Eliminate potential conflicts with right-turning cars and bicyclists using outer lanes
- Lead to faster travel times than curbside lanes and stations
- May eliminate left-turn lanes for other traffic
- May be designed as either one central median station or two separate, offset stations

Far-side

- Allow buses to re-enter the flow of traffic when necessary in the gaps created by traffic signals
- Work best with Traffic Signal Priority systems at intersections
- Increase safety by reducing conflicts with right-turning cars and encouraging pedestrians to cross behind the bus

Near-side

- Allow passengers time to board when the bus is already waiting at a red light
- Reduce rear-end accidents caused by cars that don’t expect a bus to stop a second time after a red light for a far-side stop
- May decrease visibility of crossing pedestrians by blocking sightlines from adjacent traffic lanes
**Mid-block**

- Minimize sightline and sight distance problems for both vehicles and pedestrians
- Require additional space to construct
- Encourage jaywalking to access

**Ride-side Door Access**

- Compatible with common bus designs
- May limit the options for median station designs

**Left-side Door Access**

- Require purchase of less common and more expensive bus designs with doors on both sides
- Enable the construction of combined median stations without complicated methods to move buses to the “wrong” side of the road and back

**Station Design**

BRT stations are designed to create both faster travel times and a more pleasant experience for the users. Features like platform level boarding, ticket vending machines and real-time displays elevate the system beyond the stereotypical bus experience. The stations are also often designed to be larger, more substantial, more accessible, and more visually striking than local bus stations. These differences help both brand the system as a separate service and increase passenger comfort and safety.

**Structure**

**Platform Level Boarding**

Platform level boarding is a key element of a successful BRT system. Instead of having passengers board by stepping up from curb level, the entire station is raised about 14” above street level in order to be even with the bus entryway. This design greatly improves accessibility, because people who have difficulty climbing steps or use assisting devices like walkers and wheelchairs can travel smoothly across an even surface instead of facing an elevated step. Additionally, the increased ease boarding reduces travel times on the system because each individual passenger can enter the bus slightly faster than before.

**Shelter**

Even simple shelters consisting of little more than a roof can greatly improve the user experience by protecting waiting passengers from rain or snow and shading them from the hot sun in warmer weather. Enclosing the back and sides of the shelter with walls adds protection from the wind, which can be vital in cold climates where wind chill can dramatically reduce the perceived temperature.
Modular Design

A modular approach to design involves breaking the overall structure into units that can be plugged together in different combinations. For BRT shelters, larger stations can be created by linking the structure of multiple small stations together. Modularity creates flexibility in design with relatively few design components and enables stations to be easily expanded if ridership increases in the future.

Cohesive Branding

When buses are already commonplace in a city landscape, a distinct brand and design can alert the public that a new service is now available and help reset expectations about the merits of bus travel. A distinctive design and color scheme for BRT stations, buses, and other signs or structures throughout the corridor can both create a sense of cohesion and improve visibility for the system as a whole. Additionally, users can locate branded stations more easily than simpler, non-descript designs that blend into the surroundings.

Amenities

Seating

Providing places for users to rest can greatly increase their comfort while waiting at the station, particularly for people with physical challenges that make standing for long periods of time difficult. One seating or leaning position for every five waiting passengers and space for at least one person using a wheelchair to wait under shelter is suggested to promote accessibility for all users.

Lighting

Lighting increases the sense of security for waiting passengers and makes locating stations easier for both users and bus drivers. Lights can also be used to as a design element to create a unique brand for the BRT system.

Heating

Station heating can greatly increase comfort for passengers in cold climates. However, the infrastructure for heating is more costly to install and requires significant electricity costs to run throughout the winter.

Maps and Wayfinding

Maps of the surrounding area and outlines of the route itself help users orient themselves and make navigating the BRT system easier, particularly when passengers are travelling to a new destination.

50 http://alistapart.com/article/language-of-modular-design
Real-Time Displays

Providing real-time information on when buses will arrive reduces uncertainty among passengers about how long they will be waiting. Displaying arrival times in the station itself enables passengers to quickly check the information without needing to use a phone.\textsuperscript{55}

Ticket Vending Machines

Paying bus fares with cash is a relatively slow process compared to automatically scanning a bus pass card. Ticket vending machines allow customers to purchase tickets while waiting in the station, significantly reducing the time it takes to board the bus and speeding travel times on the system overall.\textsuperscript{56}

Bike Storage

Providing bicycle storage at stations increases the accessibility of a BRT system by enabling bicyclists to complete part of their trip by bike and part by bus with the knowledge that their bike is being stored safely.

Milwaukee Rapid Transit

Implementing a BRT system through the East/West Corridor of Milwaukee poses unique design opportunities and challenges as the proposed line travels through multiple possible destinations, including downtown, Marquette University, Miller-Coors Brewing, and the Milwaukee Regional Medical Center in the adjacent suburb Wauwatosa. The corridor varies in size, scale and density, with different street widths, parking challenges, safety issues, and other unique features from location to location.

East-West Corridor

The following principles were used to guide the design of the BRT system for the East/West corridor along Wisconsin Ave.

Create a safe and accessible corridor for all users.

Thoughtful lane design, buffers, signage, and other techniques can reduce the potential for conflicts between buses and other vehicles, bicyclists, and pedestrians along the East/West corridor. Passengers need to feel safe in order to use the BRT system, but most stations will be located along arterial streets with heavy traffic, which can be particularly intimidating for pedestrians to cross. Additionally, lighting can increase visibility at night and provide an additional sense of security for BRT users.

Promote multimodal transportation by providing facilities for walking, bicycles, and vehicles.

While pedestrians must be able to access the stations themselves, Wisconsin Avenue is also a major means of access for individuals travelling to businesses and homes along the corridor by car, bus, and bicycle. While adjacent roads could handle some diverted traffic, maintaining sufficient travel lanes for other vehicles and preserving as many parking spaces as possible will help the new system gain public approval. Providing bicycle lanes or alternative means for bicycle travel in addition to facilities like bike


racks and storage will also enable more people to use the system and promote integration of the new BRT system with existing travel networks.

Create inviting and attractive streetscapes.

Because users will spend at least some time traveling to and waiting at stations, an attractive surrounding environment will greatly enhance the user experience. Landscaping, accent lighting, and decorative details like bricks and tiles enhance the character and quality of the street and are much more inviting to potential passengers than an empty concrete slab. Additionally, creating a pleasant experience for users travelling to BRT stations on foot or by bicycle will encourage those users to cover the longer distances between stations compared to local bus service. Finally, an attractive environment will improve the image of the system in the mind of the public and encourage additional ridership.

Key Location Examples
For the purpose of this report, the design team has focused on three location points along the corridor to analyze the current conditions and discuss and highlight the design strategies and techniques used. Those locations are the following:

- 4th Street and Wisconsin
- 16th Street and Wisconsin
- 27th Street and Wisconsin

4th and Wisconsin

Current Conditions

This location offers the best opportunity for a major hub station along the East/West corridor. The Grand Avenue Mall, the Wisconsin Center, and other businesses and apartments surround the area, while a parking lot on the southwest side of the 4th and Wisconsin intersection provides room for constructing a larger station or even widening the right-of-way if necessary. Additionally, existing MCTS lines already stop at this location and could be integrated with the new BRT system to maximize the travel options for riders. A Bublr Bikes station is also located just to the north of this area along the west side of 4th Street. In the future, the Milwaukee Streetcar plans to expand one of its routes to run north and south along 4th Street to connect the Milwaukee Intermodal Station with the arena district. A major streetcar stop could also be located near this intersection, providing an opportunity to integrate the systems by making transferring between them fast and easy.

However, this section of Wisconsin Avenue is only about 48’ wide, which limits some corridor design options. Currently, one travel lane in each direction runs along the center of the street, while parking, bus stops, and loading zones edge the sides.

Proposed Changes

Due to the narrow width of the street at this location, curbside stations are the only feasible option without major reconstruction and possibly right-of-way purchases to widen the roadway. However, an overarching roof across the street between the two stations would help create the feeling of a one larger, unified and more impressive station. Cars and other vehicle traffic passing through this section of
the corridor would travel underneath the roof next to the bus-only lanes and stops, which would be separated from normal travel lanes with colored pavement, bus-only text, and rumble strips.

Pedestrians would be able to access this station from either sidewalk, while landscaping both to either side of the station and along the sidewalk itself creates a more inviting, attractive streetscape for the area. Parking is already highly restricted in this area, so on average the loss of parking spaces would be around 12 - 14 per block, as opposed to roughly 25 spaces per block if more parking was currently allowed. Bicycle lanes are not currently provided on Wisconsin Avenue, and in this proposed corridor design would not be added due to the narrow width of the roadway. Instead, bike lanes could be provided on adjacent east/west streets, such as Wells Street to the north of Wisconsin Avenue, and bike racks and covered bike storage would be provided near the proposed BRT stations.

In the future, this section of Wisconsin Avenue from the Milwaukee River to 5th or 6th street could be closed to private vehicles and become a pedestrian, bicycle and transit mall. Additional studies on traffic flow, population density, and other factors would be needed to determine if closing the street would be feasible in this area. While some transit malls have been a continuous success, such as the Denver 16th Street mall, many fail and are later reopened to vehicle traffic. However, if successful, a transit mall could have the dual benefit of speeding bus and BRT services and enhancing street life in the heart of downtown Milwaukee.

16th and Wisconsin

Current Conditions

This proposed stop location lies just to the west of the Marquette campus. The roadway is relatively wide at 78’ curb-to-curb and consists of two travel lanes in each direction separated by an extensively landscaped median to the east of 16th Street and a narrow concrete median to the west. Parking is available on both sides of Wisconsin Avenue west of 16th but prohibited to east within the Marquette campus. Multiple bus lines currently run east-west along this section of corridor and stop at this location.

Proposed Changes

The larger street width in this section of the corridor permits both curbside and median far-side station designs. Either option would maintain or exceed the current level of central median landscaping to complement the existing Marquette campus design. While a few parking spaces would be lost where the stations themselves are located, parking along the center portion of the block would be maintained. However, one major limitation of the median station design for this location is that left-turn lanes would be lost unless some of the landscaped median near the intersections is eliminated.

With median stations, pedestrians would be able to access the stations from the crosswalk. A ramp rising 14” from street level would enable ADA access to the raised boarding platform of the BRT system. With curbside stations, pedestrians would access the station directly from the sidewalk, and only an 8” ramp would be necessary to reach platform boarding level.

57 An estimated 60-70 spaces would be lost along the 5 blocks between the Milwaukee River and 6th Street, which is equivalent to 12 - 14 spaces per block.
58 http://nacto.org/docs/usdg/pedestrian_and_transit_malls_study_center_city_commission.pdf
27th and Wisconsin

Current Conditions

Wisconsin Avenue at 27th Street is also 78’ curb-to-curb and features two travel lanes in each direction with parking permitted along the sides of the street. Narrow concrete median curbs run along the center of the street and become wider concrete medians or landscaped medians to the east and west of this location. Multiple bus lines travelling both east and west along Wisconsin Avenue and north and south along 27th Street serve this location.

Proposed Changes

Similar to the corridor at 16th and Wisconsin, the street width is wide enough to permit both curbside and median station designs. Parking can be preserved in either case except for by the stations themselves. For the curbside alternative, the current median arrangement can be kept, while for median stations new, larger landscaped medians would be installed. Additionally, unlike the 16th and Wisconsin location, the left turn lanes can be preserved without reducing the size of the landscaped medians.

MRT Stations

Stations are the gateways to the BRT system, creating the first visual impression and heavily influencing customer perception. The station design and the amenities offered within the station further shape the customer experience and also distinguish the BRT system from other transit services.

In order to create a successful station design, the following four principles were developed.
Create a comfortable and accessible station for all users.

In order to gain and retain riders, especially riders who would otherwise travel by car, a BRT system must provide a pleasant experience for its users. Ramps, handrails, and even elevators can be used in station design to ensure accessibility for all riders, while amenities like seating and lighting improve the experience for waiting passengers. Also, enclosed stations are more comfortable in cold, rainy, windy, or other inclement weather conditions.
Develop a cohesive system image.

Using the same colors, designs, and logo for BRT stations, buses, signage, and website helps to brand BRT as a cohesive system, to increase visibility for both users and non-users, and to promote BRT as a unique service from local bus systems. Distinctive, eye-catching stations can even become an icon of the city.

Employ proven design techniques to help passengers board more quickly in order to reduce system travel times.

Station design can affect the overall speed of a BRT system by shortening or lengthening dwell times, which is the length of time a bus remains stopped at a station while passengers board. Features like platform level boarding and off-board fare collection through ticket vending machines make it easier for users to board the bus quickly and can shorten dwell times significantly.
Employ modular station design to simplify construction and enable future flexibility.

The modular design approach involves breaking the overall structure into units that can be plugged together in different combinations. For BRT shelters, larger stations can be created by linking the structure of multiple small stations together. Modularity creates flexibility with relatively few design components and enables stations to be easily expanded if ridership increases in the future.

**Station Design**

A large modular MRT median station would feature a structure about 10’ wide by 36’ long on a platform raised 14” from street level. The open side of the platform where passengers can board the bus is marked with a high-contrast visibility strip in order to alert people of the potential danger of stepping off the edge accidentally, while a ramp provides access from the crosswalk. Additionally, the stations are enclosed on the sides and back in order to make the stations comfortable during winter months and inclement weather. Approximately 35 people could comfortably wait underneath cover in such a large station, while the smallest modular station design of 5’ by 12’ could shelter 5 - 6 people at once. One challenge for station maintenance in the Milwaukee climate is snow removal, but BRT stations could be cleared by city workers or local contractors in the same manner that existing MCTS stations are currently cleared.

When designing the overall appearance of the stations, the industrial heritage of Milwaukee was used as an inspiration. Materials commonly associated with industrial heritage such as concrete, steel, and glass were used in simplistic patterns that convey a consistent, recognizable image between stations. In addition to the architectural design of the stations, the name Milwaukee Rapid Transit and a corresponding MRT logo were developed to create more explicit branding of the system. The name
Milwaukee Rapid Transit is simple, easy to remember, and communicates the goal of BRT to create speedy public transportation. The bold orange logo catches attention and makes the system easy to identify even from a distance, while the slant of the letters and horizontal white lines imply movement and speed. This logo could be incorporated into the stations and buses along with system route maps and other media.

Modular stations with the same design would be implemented at most stations. However, at major hub locations like 4th and Wisconsin, larger, more substantial and more unique stations could create a greater sense of permanence and enhance the overall image of the system.

**Station Amenities**

Station amenities play an important role in the attractiveness of the BRT system, and higher quality amenities help separate BRT from regular bus services. Amenities that were included in the design of the MRT stations included: seating, lighting, maps, real-time displays, ticket vending machines, as well as bike storage.
The MRT stations have both interior and exterior seating options, giving users plenty of spaces to rest comfortably while waiting for the next bus. General lighting has been provided above and around stations as well as at intersections to help create visibility and a sense of security. Additional accent lighting is located along the crosswalks and ramps to the stations, which can highlight changes in levels or materials, act as a form of wayfinding, and help create a sense of place and attractiveness for the stations even at night.
Real-time displays were included in the MRT stations to provide users with accurate information on bus arrival times, alerts, and other relevant information. The stations are also equipped with route maps indicating the previous and following MRT stops, as well as information on nearby MCTS routes. Both of these features will increase the ability of riders to simply walk up and board the next MRT bus without extensive route planning beforehand.
Most of the MRT stations include off-board fare collection through ticket vending machines that allow passengers to purchase their tickets while waiting for the bus to arrive. Passengers can buy tickets with cash via the ticketing machine or digitally through payment apps and e-notifications. Off-board fare collection technology will speed up the MRT system by reducing dwell times and will also help project an image of modern, high-quality transportation.
Solar panels have also been incorporated on the roofs of the stations. The panels can help provide power for lighting, real-time displays and ticket vending machines. In addition to creating a green, environmentally friendly image for the MRT brand, the long term cost savings of reduced grid energy consumption will offset the initial costs of implementation.
The MRT stations feature adjacent bike storage options like bike racks and covered bike parking. Though bike lanes have not been included in the Wisconsin Avenue corridor, accommodating riders who use bikes to get to and from the station is essential. These bike storage areas are typically located in front of the entrance to the station so that users can lock their bikes securely before proceeding into the station.

**Recommendation**

In conjunction with the engineering team, we recommend a median station BRT system where possible along the East-West Wisconsin Avenue corridor. Wisconsin Avenue is significantly narrower east of I-43, so curbside stations may be the only practical option for this portion of the system. Despite this limitation, the proposed hub station at 4th Street and Wisconsin Avenue could use an overarching roof connecting the two curbside stations across the road to create a landmark for MRT both physically and in the minds of Milwaukeeans.

Median stations west of I-43 will speed travel times for the new system and help create a unique image that separates MRT from local bus travel. Modular stations at most stops will promote a consistent image while enabling future station expansions when ridership increases. A larger, unique hub station at 4th and Wisconsin will accommodate higher projected ridership at that location, create a landmark image of MRT in Milwaukee, and promote nearby development as the popularity of the system and the station grows.

Stations will be designed to be comfortable and fully accessible to users with features like seating, platform level boarding and ramp access. The stations will also help improve the speed of the buses traveling along the Wisconsin Avenue corridor with amenities like ticket vending machines. The use of 60’ articulated buses with branding and special coloring like the proposed MRT logo along with corresponding branding of stations will further contribute to the feeling of a cohesive, high-speed BRT line.
3. Management & Economics

East West Corridor BRT Cost-Benefit Projections

Based upon the analysis of other successfully implemented BRT lines around the country and other studies, a calculator (included as an attachment) was devised to provide projected cost-benefit analyses spurred by a potential BRT line in the east-west corridor. This is the preliminary analysis for a seven mile line in Milwaukee running along Wisconsin Avenue between The Couture and the Milwaukee Regional Medical Center (MMRC).

Providing reliable rapid transit along this corridor was found to have the potential for many economic benefits to the region including the creation of over 700 temporary jobs (directly and indirectly), $48 million per year in time savings and traffic safety, and $3.5 billion in redevelopment and investment in a half mile radius surrounding the corridor, or more conservatively, $0.83 to $3.59 per transit dollar invested in TOD within five years. Additional benefits would include approximately $10 million saved due to a reduction in accidents in the corridor, and at least $15,000 saved from the reduction in carbon emissions, and $1.87 million from a reduction in personal passenger VMT in the corridor. This comes to a conservative total annual economic benefit estimate of almost $60 million.

These benefits from an initial capital investment of around $47 million (as much as 80% of which could be provided by federal transit grants), and very reasonable maintenance and running costs when compared to LRT (approximately $4 million annually).

Travel Time Benefits

Some of the main benefits to passengers come from reduced travel times in the BRT corridor compared to local bus travel. With less time spent in travel due to faster transit service, it is assumed that passengers will be able to spend their extra time on things that have economic value. Therefore, the time they save has value to the whole metro region. Additionally, as more commuters switch to BRT from auto, it is likely that the remaining auto users will experience reduced travel times as well due to reduced congestion.

The increased speed of the service and resulting lower wait and travel times for passengers would save riders approximately $19,000 to $22,000 total collectively each weekday (the median running alternative providing slightly higher speeds due to decreased interaction with traffic lanes and decreased dwell times) per year assuming an average wage of $13.26 per hour, as shown below in Table 1. These benefit calculations utilize the base weekday ridership numbers of the existing Gold Line, and assume the mode shift patterns discussed previously in the report for each alternative. Annual savings are calculated assuming a weekend ridership of approximately half of the weekday ridership numbers.

59 TCRP reference.
Table 3.1: Time Savings Impact

<table>
<thead>
<tr>
<th>Time savings</th>
<th>Estimated average weekday ridership</th>
<th>Daily Savings (Valued at $13.26/hr)</th>
<th>Estimated Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-build alternative</td>
<td>21,902</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curbside alternative</td>
<td>25 mins (round trip)</td>
<td>28,035</td>
<td>$155,000</td>
</tr>
<tr>
<td>Median alternative</td>
<td>28 mins (round trip)</td>
<td>29,568</td>
<td>$183,000</td>
</tr>
</tbody>
</table>

Safety Impacts

It is likely that by converting the East-West corridor for BRT, the area will experience substantial safety benefits as well. These will come as more auto drivers switch to transit, thus reducing the number of vehicles on the road, and also a result of the infrastructural changes on the street. A median-based system reduces the distance that pedestrians must cross, thereby creating a “safe-haven” and reducing pedestrian-auto crashes. Additionally, a dedicated bus lane can help by eliminating conflicts between the bus and passenger vehicles.

A savings of around $10.5 million per year could also be expected due to the increase in traffic safety. This is explained by the decrease in property damage and injuries due to the segregated bus lane, which reduces the number of conflicts between the bus and cars, and possible mode shift of drivers reducing the number of vehicles in this corridor.
Table 3.2: Safety impacts of a BRT corridor:

<table>
<thead>
<tr>
<th></th>
<th>Crashes prevented</th>
<th>Valued at</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property-damage only</td>
<td>60.9</td>
<td>$4,006</td>
<td>$243,937</td>
</tr>
<tr>
<td>Minor injuries</td>
<td>24.8</td>
<td>$28,764</td>
<td>$713,347</td>
</tr>
<tr>
<td>Moderate injuries</td>
<td>10.4</td>
<td>$450,636</td>
<td>$4,686,614</td>
</tr>
<tr>
<td>Severe injuries</td>
<td>1.9</td>
<td>$2,550,408</td>
<td>$4,845,775</td>
</tr>
<tr>
<td><strong>Total annual savings</strong></td>
<td></td>
<td></td>
<td><strong>$10,489,674</strong></td>
</tr>
</tbody>
</table>

Reduction of Emissions & Vehicle Miles Traveled

Implementation of a BRT system can lead to a reduction in VMT (Vehicle Miles Traveled) and total emissions per capita in the corridor. The elements that can lead to these shifts include higher capacity buses, and facilitation of mode-shift. Shorter dwell times and faster boarding can also reduce a rider’s exposure to high concentrations of fuel emissions.

Higher capacity buses can help reduce per capita emissions of the entire system by carrying more passengers with each trip. Additionally, encouraging more people in the corridor to utilize public transit can also lead to an overall reduction of VMT in personal passenger vehicles, thereby having a positive effect on both emissions, and congestion.

A calculation of the emissions and VMT reductions expected from each alternative are shown below. The calculations were completed using the mode-shift projection discussed earlier in the document, and assuming that each new transit rider would be switching from personal passenger vehicle. It was also assumed that each new BRT rider’s trip would ride the line an average of 250 days per year (commute to work five days a week) for a six-mile round trip. The cost of carbon is based on the EPA’s social cost of carbon⁶⁰, and allows for variation in the discount rate.

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Table 3.3: Emissions and VMT Reductions

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Curbside</th>
</tr>
</thead>
<tbody>
<tr>
<td>New daily riders (mode shift)</td>
<td>1840</td>
<td>1472</td>
</tr>
<tr>
<td>Yearly VMT reduction</td>
<td>4,029,600</td>
<td>3,223,680</td>
</tr>
<tr>
<td>Annual benefit</td>
<td>$2.33 million</td>
<td>$1.87 million</td>
</tr>
<tr>
<td>CO2 Emission reduction</td>
<td>598 metric tons</td>
<td>478 metric tons</td>
</tr>
<tr>
<td>Annual Benefit</td>
<td>$19,900 - $102,000</td>
<td>$15,900 - $82,100</td>
</tr>
</tbody>
</table>

Direct Job Creation
Creating a bus rapid transit line in the east-west corridor will have an immediate job-creation impact on the local area, as well as a likely long-term job growth impact due to increased development along the line. The immediate impact includes short-term construction, utility and manufacturing jobs, along with the planning, engineering, financing and administration needed to implement the line. In addition to the aforementioned short-term benefits, the line will constitute an expansion to the MCTS system, and thus will likely require additional maintenance and operations staff.

To calculate the number of jobs created by construction spending on the line between Prospect Ave. and 87th Street, the team utilized the latest report from the American Public Transit Association. This report concludes that an average of 15,900 jobs are supported for a year for each $1 billion of public transit capital spending. Therefore, the team was able to calculate the number of short-term jobs each alternative would likely create.

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Table 3.4. Job Creation as a Product of Capital Investment

<table>
<thead>
<tr>
<th></th>
<th>Alternative 2 (Median-based)</th>
<th>Alternative 3 (Curbside)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>$47.71 million</td>
<td>$45.94 million</td>
</tr>
<tr>
<td>Direct/Indirect jobs created</td>
<td>758</td>
<td>730</td>
</tr>
</tbody>
</table>

In addition to the short-term jobs created by the capital investment, MCTS would need to hire additional employees in order to operate and maintain the additional mileage on their system. The initial east-west corridor route would add six route-miles to the transit system. Though detailed information about the new system’s operational costs would be needed to make an accurate estimate, according to their 2014 annual report, MCTS currently has 1,045 full-time employees for 1,195 bus miles, a ratio of approximately .87 employees per route mile.\(^2\) Therefore, the new route would require the hiring of approximately 5.2 full-time equivalents.

Though we estimate the new route will require nine new buses operating at peak hours, hiring levels could be kept lower than this due to service shifts away from the current Wisconsin Ave. routes, particularly the Gold Line, to the new BRT service. Thus, current drivers would be expected to take over much of the operational duties.

Transit-Oriented Development

The BRT line proposed here has good potential to support transit-oriented development (TOD). This type of development is characterized by its mix of uses, density, and walkability, typically within a half mile of a transit station.

Transit-oriented development can result in a wide range of direct public and private sector benefits, including revitalized neighborhoods and increased ridership and fare box revenues. It can also result in new construction jobs, increased land values, and higher rent premiums for property owners.\(^3\)


Transit-oriented development can also result in an array of *indirect* benefits, including increased property and sales tax revenues, decreased traffic congestion, lower motor vehicle-related costs, lower crime rates, increased retail sales, and increased physical activity among area residents.\(^{64}\)

Analyzing other cities’ BRT lines can help one to understand the level of TOD investment Milwaukee might leverage under certain conditions. Among these, Cleveland’s 6.8-mile, Healthline is perhaps the most comparable to the proposed east-west line in Milwaukee.

Like Milwaukee, Cleveland is a post-industrial city with a weak regional real-estate market. And like the east-west corridor line considered here, the Healthline connects two major employment centers: Cleveland’s central business district and University Circle, a concentration of educational, medical, and cultural facilities.

In the first five years it was opened, Cleveland’s $50 million Healthline leveraged $5.8 billion in private economic development.\(^{65}\) In other words, for each dollar spent on the busway, Cleveland received more than $116 of private investment. As the ITDP report illustrates, this private investment was the result of a high level of government support, including a municipal plan, a special zoning district, marketing and branding efforts, and creative financing options.\(^{66}\)

The level of Transit-Oriented Development (TOD) associated with a given transit project is dependent upon a large number of factors, many of which are not directly related to the quality of the transit project. In a 2013 study of 21 transit corridors across U.S. and Canada, the Institute for Transit Development Policy found that government support and land development potential in the corridor were greater indicators of successful TOD than the quality of the transit corridor itself.\(^{67}\)

If the east-west BRT line proposed for Milwaukee experienced a similar level of government support, a similar return could be possible. In other words, the proposed $34.7 million (median-based) alternative, could leverage around $3.5 billion in redevelopment within a similar time period.

On the other hand, private investment could be much less. The Orange Line in Los Angeles and the East Busway in Pittsburgh have experienced more modest TOD investments -- about $0.83 and $3.59 per transit dollar invested, respectively.\(^{68}\) This variability in return on investment can be traced to a number of factors, including higher project costs or project-specific factors. In Los Angeles, for example, lower TOD development has been attributed to a lack of community support for densification.\(^{69}\) In Pittsburgh, the east busway was built within a grade separated rail corridor, and economic development was not an original goal of the busway.\(^{70}\)

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\(^{64}\) Ibid.

\(^{65}\) Ibid.

\(^{66}\) Ibid.

\(^{67}\) Ibid., 104.

\(^{68}\) Ibid., 140-151.
In sum, Milwaukee the east-west corridor BRT line proposed could be used to leverage significant economic development in the corridor. The experience of Cleveland suggests this level of investment could be significant if there is a high level of government planning and support.

Another benefit of TOD is long-term job growth. As development is drawn to the corridor, the creation of additional retail, office and residential space will create additional employment opportunities along the line. It is difficult to quantify exactly how many jobs may spring up along the proposed six-mile line proposed here, but other cities provide some insight.

Cleveland saw an increase of 5,000 jobs on Euclid Avenue between 2002 and 2009, much of it in additional retail, university expansions, and clinic space. Alternatively, a 2013 study of the Eugene-Springfield, OR BRT line found that though the metro area as a whole lost jobs during the recession, the number of jobs within a quarter mile of the new line actually increased. This implies that during a period of economic growth, a BRT line can be expected to draw new employment to the metro area and increase the total number of jobs.

### Funding Options

The biggest challenge to implementing a feasible bus rapid transit project in Milwaukee County will be piecing together the funding from various sources to compile not only the capital needed to fund the construction, but also the ongoing operations costs.

Using current MCTS cost projections of approximately $85 per revenue hour, we would estimate the annual operations and maintenance costs of the new BRT line to be approximately $4 million. This cost calculation was made using the assumption of 912 bus revenue hours per week, and no additional fleet facility costs due to the additional vehicles.

<table>
<thead>
<tr>
<th></th>
<th>Weekday</th>
<th>Weekend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus hours</td>
<td>712</td>
<td>192</td>
</tr>
<tr>
<td>Annual cost</td>
<td>$3,200,000</td>
<td>$850,000</td>
</tr>
<tr>
<td>Total: $4 million</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Historically, several different federal and state funding sources have provided the majority of funding packages for BRT system installation and improvements in other projects across the country. Though not

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72 [http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1055&context=jpt](http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1055&context=jpt)
all of the funding can be provided through grants, Milwaukee should look to take advantage of these programs to fund a significant portion of the $34 million initial cost.

**Table 3.6: Possible Capital Funding Sources**

<table>
<thead>
<tr>
<th>Program</th>
<th>Requirements</th>
<th>Amount</th>
</tr>
</thead>
</table>
| FTA Small Starts Projects     | ● Total project cost less than $250 million and total New Starts funding sought is less than $75 million  
● New fixed guideway system, extension to existing system or corridor-based BRT system | Up to $75 million        |
| TIGER Grant Program           | ● Provides competitive, merit-based capital funding to surface transportation that help fulfill national transportation objectives. | minimum $10 million     |
| WisDOT I-94 Study             | ● Lawsuit may have changed the way WisDot funds transit through their highway projects  
● Zoo interchange settlement provided temporary transit funding at 0.8% of total project cost  
● Could be used to fund the initial planning and engineering study | $6.8 million (at current cost estimate) |

**Table 3.7: Possible Operational Funding Sources**

<table>
<thead>
<tr>
<th>Program</th>
<th>Requirements/Assumptions</th>
<th>Amount</th>
</tr>
</thead>
</table>
| Regional Transit Authority | ● Establishment of a regional transit authority and implementation of 0.5% sales tax to fund transit operations  
● Requires approval of state legislature                                                                 | $69 million annually from Milwaukee County |
| County Wheel Tax       | ● County has the ability to charge an additional fee on each vehicle registered in Milwaukee County  
● City of Milwaukee already charges $20  
● 543,000 vehicles in County according to 2014 census data                                                            | $5.4 million annually (based on $10 fee)     |

**Attachments:**

1. BRT Benefits Calculator
2. BRT Standards Calculator
PART III – PLANNING FOR THE FUTURE OF BUS RAPID TRANSIT

If implemented, what will Milwaukee’s Bus Rapid Transit system look like in 2035? What will it look like in 2050? Who will these future routes serve, and where will the busses take them? The proposed east-west Bus Rapid Transit route outlined earlier is but one small portion of a potentially region-wide system. Should this initial route be successfully implemented, future route extensions and additions should be fully explored.

The following section takes the current proposal beyond the initial east-west corridor route and analyzes the potential for future BRT extensions and their implications for the Milwaukee metropolitan area.

In this chapter, three alternatives are presented, each detailing a different approach to BRT in Milwaukee: (1) A no-build scenario, in which the status quo is maintained; (2) a BRT system that maximizes infrastructure efficiency operating solely within Milwaukee County, and; (3) a truly expansive system that emphasizes building region-wide connections.

Planning Considerations and Guiding Principles

A set of fundamental planning considerations and guiding principles was established to direct route creation prior to determining the routes that would make up the proposed alternatives. These principles were determined through research of successful Bus Rapid Transit systems across the country and throughout the world.

Efficiency

Travel-time savings is the most important feature of BRT. These time savings can encourage commuters who are otherwise not inclined to use public transportation, to considering leaving their personal vehicle at home. A decrease in single-occupancy commuting within a region can lead to a reduction in congestion, noise and air pollution and significantly reduce a region’s expenditure on road expansion and maintenance costs.\(^{73}\) It is therefore necessary to select routes that allow rapid transit busses to travel between two destinations at a rate faster than normal bus services.

An analysis of current North American BRT routes and systems determined that, when properly implemented, time savings range from 10-45 percent when compared to normal bus services.\(^{74}\) Routes that allow for dedicated median lanes offer the greatest advantages when it comes to time savings. Therefore, when determining the routes for Milwaukee’s future Bus Rapid Transit system, streets allowing for a dedicated median travel lane travel lane were given priority.


\(^{74}\)http://publicpolicyforum.org/sites/default/files/PickingUpThePace-FullReport.pdf
**Equity**

The Milwaukee region is one of the most segregated in the nation. The factors that contribute to and the implications of this unfortunate situation are complex and far-reaching. Poorer populations are burdened with longer commute times to ever more distant employers, goods and services. Economic mobility becomes increasingly difficult as access to jobs, goods, and services declines. Therefore, transportation and equity are inexorably linked.

A regional Bus Rapid Transit system can help reverse the trend of decreasing job accessibility by creating a more equitable and regionally connected transit. By allowing a greater portion of disadvantaged populations to access employment centers, a BRT system can help relieve poverty within Milwaukee’s most economic distressed neighborhoods.

Prior research has demonstrated that bus rapid transit can have modest positive impacts on economic and racial disparities. BRT systems, especially those in the developing world, have increased access to previously inaccessible employment centers for large portions of disadvantaged populations. The increase in accessibility resulted primarily from decreases in travel time and increases in regional coverage.

Therefore, it was critical to choose routes that served disadvantaged populations while emphasizing accessibility to employment centers and travel time savings. The equity analyses (described in detail in the Alternative Analysis portions of this chapter as well as Appendix B) included family poverty rates, access to a personal vehicle, and racial distribution. Additional considerations included access to necessary services, such as medical centers, and areas of high job density.

**Redevelopment**

Bus rapid transit systems have demonstrated the ability to encourage redevelopment along routes and near stations. It is hoped that this ability can be harnessed to encourage more development in the Milwaukee County. Between 1960 and 2000, the City of Milwaukee’s population decreased by nearly 20 percent. Locating BRT corridors near sites with underused parcels will encourage reinvestment in distressed areas and will serve to capitalize on recent demographic trends that suggest a renewed interest in living and working near downtown.

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78 “The Impacts of Neighborhoods on Intergenerational Mobility.” Chetty, Raj and Nathaniel Hendren. 2015.
79 These figures were collected through the United States Census Bureau’s databases and analyzed on a census tract level using Esri ArcGIS.
Prior research has indicated that vacant and underdeveloped parcels of land within a half mile of a BRT route and station saw greater increases in property value and higher rates of development and redevelopment than those beyond a half-mile.\textsuperscript{84} Therefore, when determining routes for Milwaukee’s future BRT system, routes located along corridors with significant development and redevelopment opportunities, including vacant and underdeveloped land, were given priority over those with fewer of these opportunities.

For the redevelopment analyses (described in detail in the Alternative Analysis portions of this chapter as well as Appendix B), vacant parcel and building locations were considered a proxy for development potential. While this analysis provides a basic understanding of the land available for redevelopment, additional analysis of the area’s economic trends is required, but beyond the scope of this report.

**Activity Center Selection, Route Establishment, and Station Location**

Research conducted prior to the creation of routes found significant evidence that a common and effective approach to establishing Bus Rapid Transit systems is quickly connecting activity centers, rather than enhancing existing bus routes.\textsuperscript{85,86} The activity center connection method seeks to identify a series of regionally-significant locations, or activity centers, by identifying hot spots for commercial, employment, educational and entertainment activities. BRT routes are then drafted to connect these locations logically and methodically, with the aforementioned three planning principles. This method formed the basis for establishing the Bus Rapid Transit routes in the Milwaukee metropolitan region for this report.

**Activity Center Selection**

Key activity centers were selected through both extensive data collection and local knowledge of the Milwaukee metropolitan region. Potential activity centers were divided into four broad categories - commercial, employment, institutional and cultural/entertainment (Appendix B). A description of the types of activity centers and the data utilized to determine where in Milwaukee they are located is as follows:

*Commercial:*  
Commercial activity centers were established using data available through Esri Business Analyst. Esri extracts business data, including the business name, location, franchise code, industry classification code, number of employees, and sales volume from more than 13 million US businesses\textsuperscript{87}. This information allowed easy identification of commercial bright spots. Areas with particularly high levels of sales volume were noted and included on a list of commercial activity centers.

*Employment:*  
A similar approach was used for employment nodes, relying of the number of jobs per census tract in order to identify key employment

---

\textsuperscript{85} Background Report  
\textsuperscript{87} ESRI, Infogroup, BLS
activity centers. Again, census tracts with high levels of job density were included on a list of regionally important locations for a Bus Rapid Transit System to serve (Appendix B).

**Institutional & Cultural:**

Institutional and cultural nodes were both selected through an informed knowledge of the Milwaukee region’s key educational and cultural facilities. Institutional nodes primarily included colleges, universities and health care facilities, including the University of Wisconsin-Milwaukee, Marquette University, Milwaukee Area Technical College, the Medical College of Wisconsin, and the Milwaukee Regional Medical Center. Cultural and entertainment nodes included sports facilities, museums, zoos, casinos and fair grounds.

**Route Establishment**

Prior to the establishment of the three alternatives, an in-depth analysis determined that several forms of BRT used in other cities would not meet the three primary planning objectives.

Dedicated freeway lanes, while providing the fastest travel times between activity centers, do not encourage additional investment and provide only limited access to those without vehicles.\(^88\) Because current densities along freeway corridors is low, and living next to these busy routes is considered undesirable, there is little opportunity to leverage this form of BRT into significant private reinvestment and redevelopment.

The sheer size and limited crossing opportunities of modern freeways make them difficult to access by those without vehicles or those who choose to walk or bike. The scale and layout of Milwaukee’s freeway system can also make finding locations for potential transit stations a challenge.

The Milwaukee County Transit System currently offers several “freeway flyer” routes which are only accessible via park-and-ride lots. This flyer system fails to provide adequate accommodations for inner city residents and those without vehicles. It primarily serves high-income suburban residents who commute to downtown Milwaukee. A BRT system built on a dedicated freeway lane would likely face many of the same issues and would fail to serve disadvantaged populations.

A Bus Rapid Transit system utilizing a separated right-of-way along existing railways or grade separated roads was also initially considered a possibility. However, upon an analysis of infrastructure costs and potential equity and redevelopment benefits, it was determined that this form of BRT leaves little opportunity for redevelopment,\(^89\) while simultaneously being prohibitively expensive.

The infrastructure cost a new right-of-way for BRT along grade separated roads or in former rail corridors is comparable to light rail. Light rail infrastructure typically cost between $75-$100 million per mile – ten times that of an on-street BRT systems.\(^90\) Despite additional time savings afforded by separated right-of-way, the infrastructure costs would require the scope of the system to be scaled back dramatically.

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Additionally, most the opportunities for exclusive BRT right-of-ways in the Milwaukee region are along former and underused rail corridors. These rail corridors provide additional challenges due to the lack of immediately adjacent activity centers, with the notable exception of the 30th Street Industrial Corridor. Many of these rail corridors also face similar limitations as BRT systems utilizing dedicated lanes on freeways. Namely, they leave little potential for redevelopment and are more difficult to access for those with limited incomes and mobility.

Due to these challenges, it was determined that a BRT system using dedicated on street lanes has the highest chance of success in the Milwaukee metropolitan region. To keep other vehicles from utilizing these dedicated lanes and potentially slowing down BRT busses, rumble strips, curbs or medians will notify drivers that the lane is off limits. With this in mind, routes were then drafted to connect at least five of the pre-selected activity centers, while employing the three planning considerations of efficiency, equity and redevelopment, along with the corresponding supporting data outlined above.

As a route was completed, it was checked against these data, such as the percentage of families served in poverty or available acres of vacant developable land, to ensure they met the criteria for an effective Bus Rapid Transit system. Routes were reworked if they did not meet the guiding principles. Please see Appendix B for a complete analysis of the proposed route alternatives.

**Station Location**

Selecting station locations was a simpler process. Prior research indicated that significant time savings with BRT are only possible with stations spacing of a half-mile to one mile apart. Stations were first placed at the major activity centers. Station locations between the major activity centers were based on either intersections with current local service or locations with redevelopment potential. There were certain locations where this technique reduced the stop spacing to less than half a mile. Therefore some stations were removed despite being a location that intersects with existing local service. In those instances it is recommended MCTS modify its local service to “feed” the BRT lines.

**Alternatives & Analysis**

As stated above, the chapter presents three alternatives: a no-build scenario in which the status quo is maintained, a BRT system that maximizes infrastructure efficiency operating solely within Milwaukee County, and a truly expansive system that emphasizes building region-wide connections. A snapshot comparison of each alternative and the initial east-west corridor route is provided below, followed by brief description and analysis of each alternative. For a full analysis of each alternative, including system-wide maps and statistics, please refer to Appendix B.
## Snapshot Comparison

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Alternative 0</th>
<th>Alternative I</th>
<th>Alternative II</th>
<th>Alternative III Private ROW/Express Routes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>%</td>
<td>#</td>
<td>%</td>
</tr>
<tr>
<td>Routes</td>
<td>7</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Route Mileage</td>
<td>112</td>
<td>-</td>
<td>79</td>
<td>-</td>
</tr>
<tr>
<td>Population Served</td>
<td>432,383</td>
<td>-</td>
<td>348,498</td>
<td>-</td>
</tr>
<tr>
<td>Estimate Ridership</td>
<td>74,468</td>
<td>-</td>
<td>50,266</td>
<td>-</td>
</tr>
<tr>
<td>Number of Jobs Served</td>
<td>264,148</td>
<td>-</td>
<td>279,767</td>
<td>-</td>
</tr>
<tr>
<td>Redevelopment Potential</td>
<td>-</td>
<td>-</td>
<td>700 acres</td>
<td>-</td>
</tr>
<tr>
<td>Population Below Federal Poverty Line</td>
<td>210,000</td>
<td>-</td>
<td>190,000</td>
<td>-</td>
</tr>
<tr>
<td>Racial Diversity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>White</td>
<td>225,970</td>
<td>54%</td>
<td>184,292</td>
<td>55%</td>
</tr>
<tr>
<td>Black</td>
<td>152,112</td>
<td>36%</td>
<td>119,412</td>
<td>35%</td>
</tr>
<tr>
<td>Asian</td>
<td>17,460</td>
<td>4%</td>
<td>11,883</td>
<td>4%</td>
</tr>
<tr>
<td>Other Races</td>
<td>6,581</td>
<td>5%</td>
<td>20,822</td>
<td>6%</td>
</tr>
</tbody>
</table>
Alternative 0: No-Build Scenario (Existing Conditions)

This scenario serves as the no-change solution. Milwaukee County Transit System currently runs several Express Routes throughout the region. These routes are different from freeway fliers, in that the run a-grade and, in some ways, serve as a BRT lite model. Buses running along these routes stop less frequently than the non-express buses along the same routes, resulting in time savings, though minimal. Several of these routes also serve the Milwaukee suburbs and crucial employment nodes. The Goldline and the New Berlin Express line extend outside of Milwaukee County, with later services offered for the business parks located along Moorland Road. The Redline Express also extends out into Waukesha County along Capital Drive.

Current MCTS Express Routes Map
**Alternative I**

Alternative I features 79 route miles, across 5 unique routes, and emphasizes route consolidation in order to minimize costs. Routes run exclusively in Milwaukee County and do not extend out far beyond current services. Alternative I also proposes a special events route, which would be in service during times in which events are being held at Miller Park in the Menomonee Valley. The route system analysis focuses on one-half mile distances from the routes. The demographic information and other data within ten minute walking distance buffers could reflect the characteristics of the captured serviceable population. Based on the United States Census Bureau data and GIS analysis, this proposal’s routes serve 348,498 individuals and 279,767 jobs. Thirty percent of the families it serves fall below the federal poverty line. Fifty-five percent of the population it serves is White and thirty-five percent is Black (Please see Appendices C for a full description and evaluation of Alternative I).

**Alternative I 0.5 Buffer Study Area Map**
Alternative II

Alternative II features 137 route miles, across 6 unique routes, and emphasizes serving as much of the region as practical. The East-West Corridor is a forked route that serves both Downtown Wauwatosa and Downtown Waukesha, merging together in Downtown Milwaukee at 6th Street. Alternative II also proposes a route that extends to the former Northridge Mall, in hopes that transit improvements in Milwaukee’s northwest side can spur reinvestment in its neighborhoods and the long shuttered shopping center. Within one-half mile, this proposal’s routes serve 456,671 individuals and 323,342 jobs. Thirty-two percent of the population it serves fall below the federal poverty line. Fifty-five percent of the population it serves is White and thirty-five percent is Black (Please see Appendices D for a full description and evaluation of Alternative II).

Alternative II 0.5 Buffer Study Area Map
**Recommendation**

After careful consideration and evaluation, it was determined that the strongest alternative is also the most aggressive and expansive. Alternative II adequately adheres to the three predetermined planning principles of efficiency, equity and redevelopment, while also serving to connect the greater Milwaukee metropolitan region through more expansive coverage.

While both Alternative I and Alternative II, would likely be able to improve on travel times between activity centers due, in part, to less frequent stops, Alternative II provides potentially faster routes along the east-west corridor. Blue Mound Road’s sizable width allows for longer stretches of dedicated, median-lane travel for BRT line, which allows for even greater time savings when compared to normal bus services. The east-west route that runs through the Village of Wauwatosa and out to the Regional Medical Center also allows for dedicated, median-lane routes and, therefore, greater time savings by running along Highland Avenue, a relatively less travelled corridor with a wide median.

Unlike Alternative I, this alternative is able to surpass the no-build scenario when it comes to meeting equity considerations. Alternative II is able to serve a greater number of families living below the poverty line, and is able to provide these populations access to a greater number of jobs through its expansive system map.

Finally, this alternative has the potential to stimulate twice the amount of development and redevelopment, when compared to Alternative I. Within one-half mile of all Alternative II routes, over 1,400 acres of vacant land lie dormant, ready for redevelopment. Within one-half mile of all Alternative I routes, there is only 700 acres of developable vacant land. Furthermore, much of the vacant land identified in the Alternative II analysis is located in large parcels on Milwaukee’s far Northwest Side, which contained some of the region’s most distressed neighborhoods. Sparking investment in these areas not only serves to address redevelopment considerations, it may also serve to address equity-related issues as well.
## Appendix A

### A.1 - Current Peak Travel Times (Alternative 1)

<table>
<thead>
<tr>
<th></th>
<th>Current Peak Travel Times (6-9am)</th>
<th>Current Peak Travel Times (3-6pm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>87th St. to Prospect Ave. (EB)</strong></td>
<td>Wisconsin Ave.</td>
<td>I-94</td>
</tr>
<tr>
<td><strong>Prospect Ave. to 87th St. (WB)</strong></td>
<td>Wisconsin Ave.</td>
<td>I-94</td>
</tr>
<tr>
<td><strong>Auto Travel Times</strong></td>
<td>32 Minutes</td>
<td>27 Minutes</td>
</tr>
<tr>
<td><strong>Transit Travel Times</strong></td>
<td>55 Minutes</td>
<td>50 Minutes</td>
</tr>
</tbody>
</table>
A.2 - Proposed Travel Times (Alternative 2)

<table>
<thead>
<tr>
<th>Proposed Peak Travel Times (6-9am)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>87th St. to Prospect Ave. (EB)</strong></td>
</tr>
<tr>
<td>Auto Travel Times</td>
</tr>
<tr>
<td>Transit Travel Times</td>
</tr>
<tr>
<td>Avg. Travel Time Reduction</td>
</tr>
</tbody>
</table>

Proposed Travel Times (Alternative 2) (Cont.)

<table>
<thead>
<tr>
<th>Proposed Peak Travel Times (3-6pm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>87th St. to Prospect Ave. (EB)</strong></td>
</tr>
<tr>
<td>Auto Travel Times</td>
</tr>
<tr>
<td>Transit Travel Times</td>
</tr>
<tr>
<td>Avg. Travel Time Reduction</td>
</tr>
</tbody>
</table>
A.3 - Proposed Travel Times (Alternative 3)

**Proposed Peak Travel Times (6-9am)**

<table>
<thead>
<tr>
<th></th>
<th>87th St. to Prospect Ave. (EB)</th>
<th>Prospect Ave. to 87th St. (WB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auto Travel Times</strong></td>
<td>32 Minutes</td>
<td>30 Minutes</td>
</tr>
<tr>
<td><strong>Transit Travel Times</strong></td>
<td>42 Minutes</td>
<td>38 Minutes</td>
</tr>
<tr>
<td><strong>Avg. Travel Time Reduction</strong></td>
<td>13 Minutes</td>
<td>12 Minutes</td>
</tr>
</tbody>
</table>

**Proposed Peak Travel Times (3-6pm)**

<table>
<thead>
<tr>
<th></th>
<th>87th St. to Prospect Ave. (EB)</th>
<th>Prospect Ave. to 87th St. (WB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auto Travel Times</strong></td>
<td>32 Minutes</td>
<td>33 Minutes</td>
</tr>
<tr>
<td><strong>Transit Travel Times</strong></td>
<td>42 Minutes</td>
<td>39 Minutes</td>
</tr>
<tr>
<td><strong>Avg. Travel Time Reduction</strong></td>
<td>15 Minutes</td>
<td>13 Minutes</td>
</tr>
</tbody>
</table>
A.4 - Capacity Calculation Procedure:

### Procedures for Estimating Highway Capacity:

**Urban One/Two/Three Lane Highway Capacity**

\[
\text{Capacity} = s0 \times n \times fW \times fHV \times fp \times fa \times PHF
\]

- **s0** = base saturation flow rate per lane (pcphpl)
- **N** = number of peak lanes
- **fW** = adjustment factor for lane width
- **fHV** = adjustment factor for heavy vehicles in traffic stream
- **fp** = adjustment factor for existence of parking activity
- **fa** = adjustment factor for area type
- **PHF** = Peak Hour Factor

#### Base Saturation Flow Rate, s0
\[
s0 = 1900 \text{ (pcphpl)}
\]

#### Adjustment Factor for Lane Width, fW
\[
fW = 1 + \frac{(W-12)}{30}
\]

*where:*  
\[
W = \text{lane width (minimum of 8, maximum of 16) (ft)}
\]

#### Adjustment Factor for Heavy Vehicles, fHV
\[
fHV = \frac{100}{[100 + HV \times (ET - 1)]}
\]

*where:*  
\[
HV = \text{percent heavy vehicles}
ET = 2.0 \text{ passenger car equivalents}
\]

#### Adjustment for Parking, fp
\[
fp = \frac{[N - 0.1 - (18 \times Nm / 3600)]}{N}
\]

*where:*  
\[
N = \text{number of lanes in lane group}
Nm = \text{number of parking maneuvers per hour}
(6 \text{ for two-way streets for parking on one side})
(12 \text{ for two-way streets with parking on both sides or one-way streets with parking on one side})
(24 \text{ for one-way streets with parking on both sides})
When parking is not allowed or unavailable, fp is set to 1.0.

#### Adjustment for Area Type, fa
\[
fa = \begin{cases} 
0.9 & \text{in CBDs} \\
1.0 & \text{elsewhere}
\end{cases}
\]
### A.5 - Potential Crash Reductions on the Wisconsin Avenue Corridor

<table>
<thead>
<tr>
<th>Category</th>
<th># of Crashes (2010-2014)</th>
<th># of Crashes (Annual Average)</th>
<th># of Reduced Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Crashes on Wisconsin Ave. (2010-2014)</td>
<td>1377</td>
<td>275.4</td>
<td>90.9*</td>
</tr>
<tr>
<td>Total Crashes with Injury Reported</td>
<td>453</td>
<td>90.6</td>
<td>37.1**</td>
</tr>
<tr>
<td>A (Severe)</td>
<td>24</td>
<td>4.8</td>
<td>1.9**</td>
</tr>
<tr>
<td>B (Moderate)</td>
<td>127</td>
<td>25.4</td>
<td>10.4**</td>
</tr>
<tr>
<td>C (Minor)</td>
<td>302</td>
<td>60.4</td>
<td>24.8**</td>
</tr>
<tr>
<td>Property Damage</td>
<td>924</td>
<td>184.8</td>
<td>60.9*</td>
</tr>
</tbody>
</table>

*Based on a crash reduction of 33% (EMBARQ, 2015). **Based on an injury reduction of 41% (EMBARQ, 2015).
### Median-Based System

<table>
<thead>
<tr>
<th></th>
<th>Median BRT</th>
<th>Car On Freeway-BRT</th>
<th>Eastbound</th>
<th>Median BRT</th>
<th>Car On Freeway-BRT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Person cost, transit (Ct)</strong></td>
<td>2.25</td>
<td>2.25</td>
<td></td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td><strong>In-vehicle travel time, transit (It)</strong></td>
<td>31.3</td>
<td>31.3</td>
<td></td>
<td>34.1</td>
<td>34.1</td>
</tr>
<tr>
<td><strong>Out-of-vehicle travel time, transit (Ot)</strong></td>
<td>9.1</td>
<td>9.1</td>
<td></td>
<td>9.4</td>
<td>9.4</td>
</tr>
<tr>
<td><strong>Person cost, vehicle (Cv)</strong></td>
<td>4.50</td>
<td>4.50</td>
<td></td>
<td>9.50</td>
<td>9.50</td>
</tr>
<tr>
<td><strong>In-vehicle travel time, vehicle (Iv)</strong></td>
<td>30</td>
<td>18</td>
<td></td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td><strong>Out-of-vehicle travel time, vehicle (Ov)</strong></td>
<td>6</td>
<td>6</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Number of vehicles in household (VA)</strong></td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Utility of transit (Ut)</strong></td>
<td>-2.36</td>
<td>-2.36</td>
<td></td>
<td>-2.53</td>
<td>-2.53</td>
</tr>
<tr>
<td><strong>Utility of vehicle (Uv)</strong></td>
<td>-3.22</td>
<td>-2.58</td>
<td></td>
<td>-3.20</td>
<td>-2.93</td>
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<tr>
<td><strong>Probability of transit (Pt)</strong></td>
<td>0.70</td>
<td>0.56</td>
<td></td>
<td>0.66</td>
<td>0.60</td>
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</tbody>
</table>

### Curb-Based System

<table>
<thead>
<tr>
<th></th>
<th>Curb BRT</th>
<th>Car On Freeway-BRT</th>
<th>Eastbound</th>
<th>Curb BRT</th>
<th>Car On Freeway-BRT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Person cost, transit (Ct)</strong></td>
<td>2.25</td>
<td>2.25</td>
<td></td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td><strong>In-vehicle travel time, transit (It)</strong></td>
<td>32.7</td>
<td>32.7</td>
<td></td>
<td>36.9</td>
<td>36.9</td>
</tr>
<tr>
<td><strong>Out-of-vehicle travel time, transit (Ot)</strong></td>
<td>9.1</td>
<td>9.1</td>
<td></td>
<td>9.4</td>
<td>9.4</td>
</tr>
<tr>
<td><strong>Person cost, vehicle (Cv)</strong></td>
<td>4.50</td>
<td>4.50</td>
<td></td>
<td>9.50</td>
<td>9.50</td>
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<tr>
<td><strong>In-vehicle travel time, vehicle (Iv)</strong></td>
<td>30</td>
<td>18</td>
<td></td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td><strong>Out-of-vehicle travel time, vehicle (Ov)</strong></td>
<td>6</td>
<td>6</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Number of vehicles in household (VA)</strong></td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Utility of transit (Ut)</strong></td>
<td>-2.43</td>
<td>-2.43</td>
<td></td>
<td>-2.68</td>
<td>-2.68</td>
</tr>
<tr>
<td><strong>Utility of vehicle (Uv)</strong></td>
<td>-3.22</td>
<td>-2.58</td>
<td></td>
<td>-3.20</td>
<td>-2.93</td>
</tr>
<tr>
<td><strong>Probability of transit (Pt)</strong></td>
<td>0.69</td>
<td>0.54</td>
<td></td>
<td>0.63</td>
<td>0.56</td>
</tr>
</tbody>
</table>
Attachments:

3. Automobile Traffic Capacity and Directional Design Hourly Volume Table
4. Travel Time Comparisons
5. Eastbound & Westbound Weekday Waiting Times at a Bus Stop
6. Mode Share Analysis
7. Transit Ridership Along Wisconsin Avenue
8. BRT Capital Costs
9. Street Sections
Appendix B

B.1: Activity Centers

B.2: Current Milwaukee Demographics & Conditions

Milwaukee Metropolitan Region Demographics, 2013

<table>
<thead>
<tr>
<th>Race</th>
<th>Population</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Races</td>
<td>1,569,659</td>
<td>100.00%</td>
</tr>
<tr>
<td>White</td>
<td>1,207,058</td>
<td>76.90%</td>
</tr>
<tr>
<td>Black/African American</td>
<td>267,767</td>
<td>17.06%</td>
</tr>
<tr>
<td>American Indian &amp; Alaska Native</td>
<td>10,782</td>
<td>0.69%</td>
</tr>
<tr>
<td>Asian</td>
<td>51,472</td>
<td>3.28%</td>
</tr>
<tr>
<td>Native Hawaiian &amp; other Pacific Islander</td>
<td>694</td>
<td>0.04%</td>
</tr>
<tr>
<td>Two or more races</td>
<td>31,886</td>
<td>2.03%</td>
</tr>
<tr>
<td>Hispanic/Latino population (may be of any race)</td>
<td>158,035</td>
<td>10.07%</td>
</tr>
</tbody>
</table>

Milwaukee Regional Employment Centers, 2013

Data Source: US Census Bureau, [http://lehd.ces.census.gov/data/](http://lehd.ces.census.gov/data/)
Milwaukee Regional Sales by Business, 2013
B.3: Alternative I

Alternative I System Map
Alternative I System Map and Population Density within Half-Mile Buffer
Alternative I System Map and Job Density within Half-Mile Buffer
Alternative I System Map and Sales Volume within Half-Mile Buffer
Alternative I System Map and Poverty Levels within Half-Mile Buffer
Alternative I System Map and Population by Race within Half-Mile Buffer
Alternative I System Map and Vacant Properties within Half-Mile Buffer

<table>
<thead>
<tr>
<th>Development Potential:</th>
<th>Vacant Property Square Footage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>5,714,418</td>
</tr>
<tr>
<td>Residential</td>
<td>16,026,486</td>
</tr>
<tr>
<td>Industrial</td>
<td>5,480,287</td>
</tr>
<tr>
<td>Special District</td>
<td>3,652,566</td>
</tr>
</tbody>
</table>
Alternative I Services Overlap with Current MCTS (Services Overlap 72 Miles)
B.4: Alternative II

Alternative II System Map
Alternative II System Map and Population Density within Half-Mile Buffer
Alternative II System Map and Job Density within Half-Mile Buffer
Alternative II System Map and Sales Volume within Half-Mile Buffer
Alternative II System Map and Poverty Levels within Half-Mile Buffer
Alternative II System Map and Population by Race within Half-Mile Buffer
Alternative II System Map and Vacant Properties within Half-Mile Buffer

<table>
<thead>
<tr>
<th>Development Potential:</th>
<th>Vacant Property Square Footage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>7,136,764</td>
</tr>
<tr>
<td>Residential</td>
<td>29,004,439</td>
</tr>
<tr>
<td>Industrial</td>
<td>15,676,699</td>
</tr>
<tr>
<td>Special District</td>
<td>9,155,434</td>
</tr>
</tbody>
</table>

Legend
- Alternative II
- Commercial
- Residential
- Industrial
- Special District
Alternative II Services Overlap with Current MCTS (Services Overlap 109 Miles)
### B.5: Separated BRT Right-of-Way System Feasibility Analysis

Separation BRT Right-of-Way System Map with Half-Mile Buffer

<table>
<thead>
<tr>
<th>Population</th>
<th>195,690</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>197,539</td>
</tr>
<tr>
<td>Sales Volume</td>
<td>$92 M</td>
</tr>
<tr>
<td>Ridership</td>
<td>53,073/ 26,684/ 64,000</td>
</tr>
<tr>
<td>Poverty Rate</td>
<td>25%</td>
</tr>
<tr>
<td>No Vehicle Access (household)</td>
<td>15,917</td>
</tr>
</tbody>
</table>

#### Racial Diversity

<table>
<thead>
<tr>
<th>Race</th>
<th>Value</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>120,551</td>
<td>64%</td>
</tr>
<tr>
<td>Black</td>
<td>53,930</td>
<td>28%</td>
</tr>
<tr>
<td>Asian</td>
<td>8,203</td>
<td>4%</td>
</tr>
<tr>
<td>American Indian and Alaska Native</td>
<td>1,112</td>
<td>1%</td>
</tr>
<tr>
<td>Hawaiian and Pacific Islander</td>
<td>15</td>
<td>0%</td>
</tr>
<tr>
<td>Other Races</td>
<td>5,454</td>
<td>3%</td>
</tr>
<tr>
<td>Sum</td>
<td>189,265</td>
<td></td>
</tr>
</tbody>
</table>