MADISON EAST-WEST BRT PLANNING STUDY

Detailed Evaluation of Alternatives

Technical Memo 2: Transportation

FINAL

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Prepared for:

City of Madison

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REVISIONS

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Overview

The Madison East-West Bus Rapid Transit (BRT) Planning Study is a 12-month study led by the City of Madison in coordination with Metro Transit and the Madison Area Transportation Planning Board (MATPB).

The project will identify and evaluate a transit investment alternative for implementation within the study corridor (Figure 1), which runs from East Towne Mall to West Towne Mall, through the Isthmus. The corridor is approximately 15 miles long.

This study expands on previous planning work to identify a locally-preferred transit investment alternative that meets the needs set forth in this document. At a high level, these needs include providing safe, efficient, and expanded levels of mobility within the increasingly busy study corridor and to improve connectivity between the corridor and employment centers.

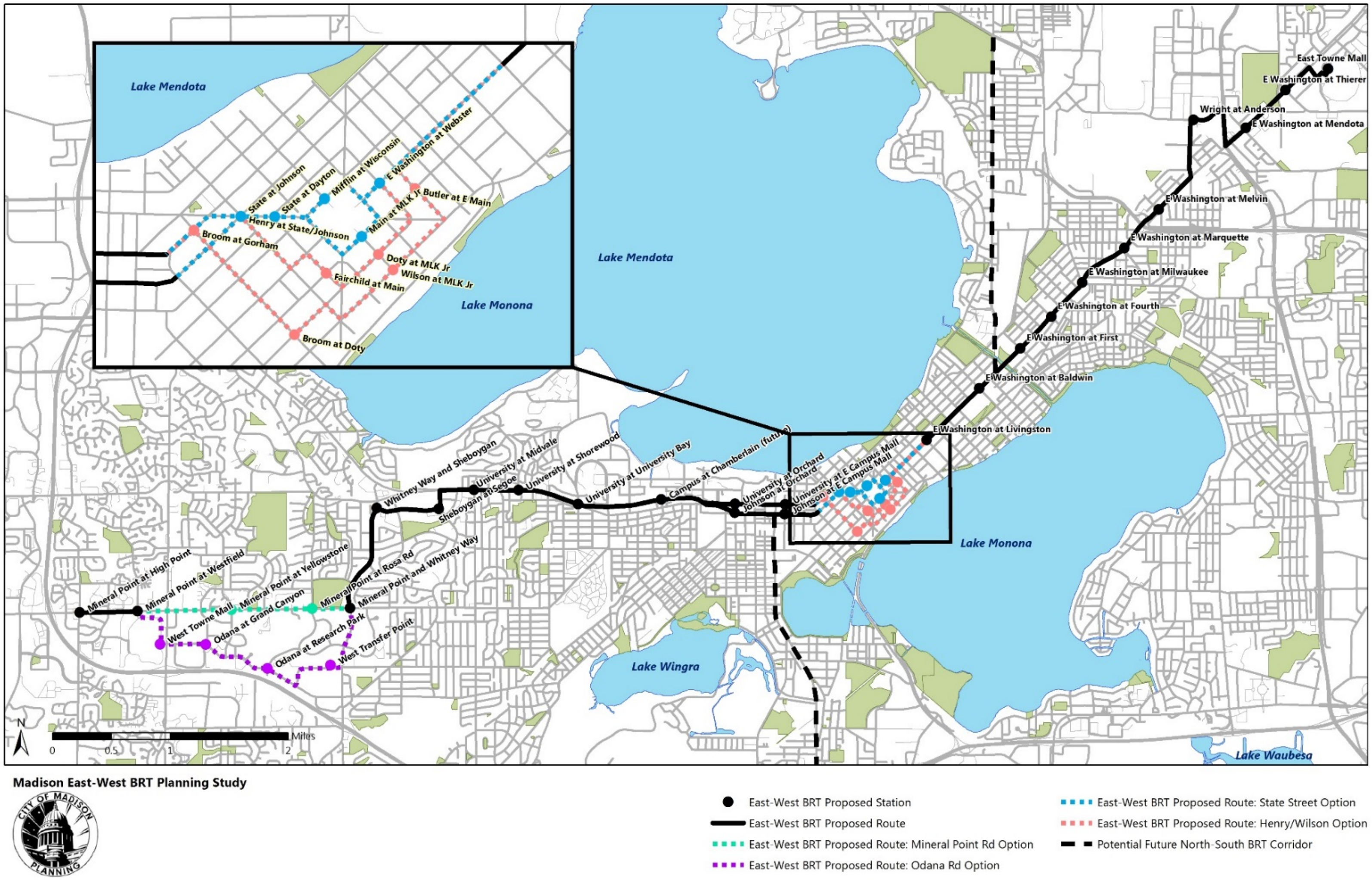
Following a multi-phase, iterative alternatives development and evaluation process that is supported by extensive public engagement activities, the City of Madison will recommend the locally preferred alternative (LPA) to the Common Council for adoption. The LPA will be the transit investment alternative that best meets the purpose of and need for the project (as defined in the Purpose and Need report) and is competitive for funding through the Federal Transit Administration (FTA) Small Starts capital funding program.

The study is scheduled for completion in fall 2019.

Corridor Context and Description

The proposed BRT corridor runs from approximately East Towne Mall on the east side of Madison, to West Towne Mall on the west side of Madison, running through the Isthmus and the University of Wisconsin (UW) campus (Figure 1). Two options on the west side will be analyzed as part of this study, as well as two options in downtown. One of each of these will be selected as part of the LPA.

Figure 1. Madison East-West BRT Corridor



Source: City of Madison

Overview of Project Evaluation Process

The East-West BRT Planning Study is following a two-phase method to identify and develop the LPA.

- Phase 1 includes the detailed evaluation of the potential alignment alternative(s). The detailed evaluation will result in the identification of the preferred alternative, including the best-performing minimal operable segment[1] (MOS), which will include a preferred alignment on the west side and around the Capitol in downtown. The alternative resulting from this evaluation will become the preferred alternative, which will advance for further refinement in Phase 2.
- Phase 2 will refine the preferred alternative selected at the end of Phase 1 to become the LPA. The LPA will include an MOS, which will be the first investment in construction of the full 15-mile corridor.

The evaluation criteria associated with each phase are a combination of quantitative and qualitative performance measures. Phase 1 will apply metrics that are linked to the project goals and objectives (as defined in the study Purpose and Need Report, available under separate cover) and will identify the preferred alternative. Phase 2 will evaluate the preferred alternative against federal criteria to determine the LPA. This two-phase process will result in the identification of an LPA that not only meets locally-identified project purpose and needs, but is also competitive for federal funding.

Table 1 presents the evaluation criteria that are likely to be used during the two phases of alternative evaluation. Phase 2 will build upon the criteria from Phase 1, ensuring a consistent rating throughout. Details of these criteria, including the methodology and screening thresholds, will be defined as the study progresses.

Table 1. Evaluation Criteria

Project Goals	**Evaluation Phases**	
	Phase 1: Detailed Evaluation	**Phase 2: Refinement of the LPA**
Increase the efficiency, attractiveness, and utilization of transit for all users	• Ridership • Transit travel times	• Mobility improvements[a]
Efficiently manage the forecasted increase in corridor travel demand	• Traffic impacts • Parking impacts • Potential right-of-way impacts • Bicycle and pedestrian impacts	• Mobility improvements[a] • Congestion relief[a]

[1] An MOS is a segment of the LPA that provides the most cost-effective solution with the greatest benefits for the project. According to the FTA, the MOS must be able to function as a stand-alone project and not be dependent on any future segments being constructed.

Project Goals	Evaluation Phases	
	Phase 1: Detailed Evaluation	Phase 2: Refinement of the LPA
Contribute to a socially-, economically-, and environmentally-sustainable transportation network	• Station area population and employment densities • Station area equity characteristics • Station area land use and economic development opportunities • Environmental impacts/benefits	• Economic development[a] • Land use [a] • Environmental benefits[a]
Develop and select an implementable and community-supported project	• Capital and operating and maintenance costs • Cost effectiveness • Community support	• Financial capacity analysis[a] • Cost effectiveness[a]

[a] *Consistent with FTA New Starts criteria.*

Technical Memo #2 Overview

Six technical memoranda (tech memos) are being prepared to describe the results of the evaluation. The six tech memos include the following:

- Tech Memo 1: Station Areas
- Tech Memo 2: Transportation
- Tech Memo 3: Potential Environmental Impacts
- Tech Memo 4: Capital Costs
- Tech Memo 5: Operating and Maintenance Costs
- Tech Memo 6: Ridership

Results contained in the six tech memos are summarized in the *Detailed Evaluation of Alternatives Report* (available under separate cover).

This report (Tech Memo 2: Transportation) presents the results of the evaluation of the alternatives with respect to three transportation sub-criteria:

- Parking Impacts
- Traffic Impacts
- Bicycle and Pedestrian Connectivity

A summary of the station area analysis can be found in the following section; the methodology, data sources, and results of the evaluation are presented after the summary.

Detailed Alternatives

As discussed in the *Detailed Definition and Downtown Routing Memo*, the corridor has been divided into segments to simplify the alternative definition and evaluation process, see Figure 2. This segmentation will facilitate the identification of the MOS through the modular organization of data. Consistent data collection and analyses will be applied along the full length of the corridor, but the results are reported in segments defined in the following subsections. This will enable a quick comparison of different combinations of segments as MOSs are developed and considered, and will facilitate internal and external decision making. These segments represent natural breakpoints in either corridor development character or right-of-way geometry.

Figure 2. Segments for the East-West BRT Corridor

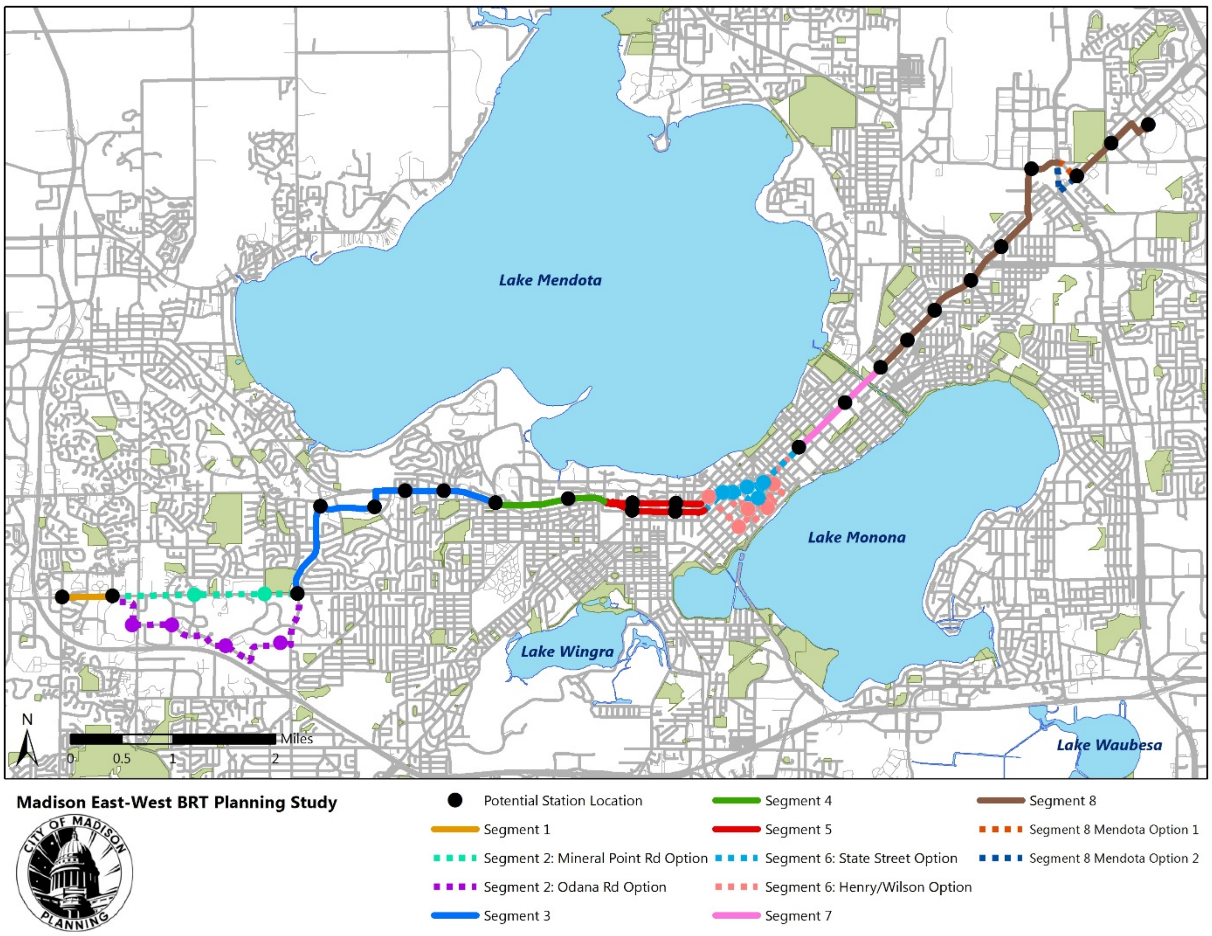


Figure 3 shows the two downtown options in greater detail. The first option runs on State Street and around the Capitol Square, then traveling east on East Washington Avenue. The second option uses paired one-way streets, Henry/Broom and Doty/Wilson to travel near the Capitol Square and is not affected by most detour events. One option will be chosen based on the results of the analysis in the next phase of this study.

Figure 3. Segment 6

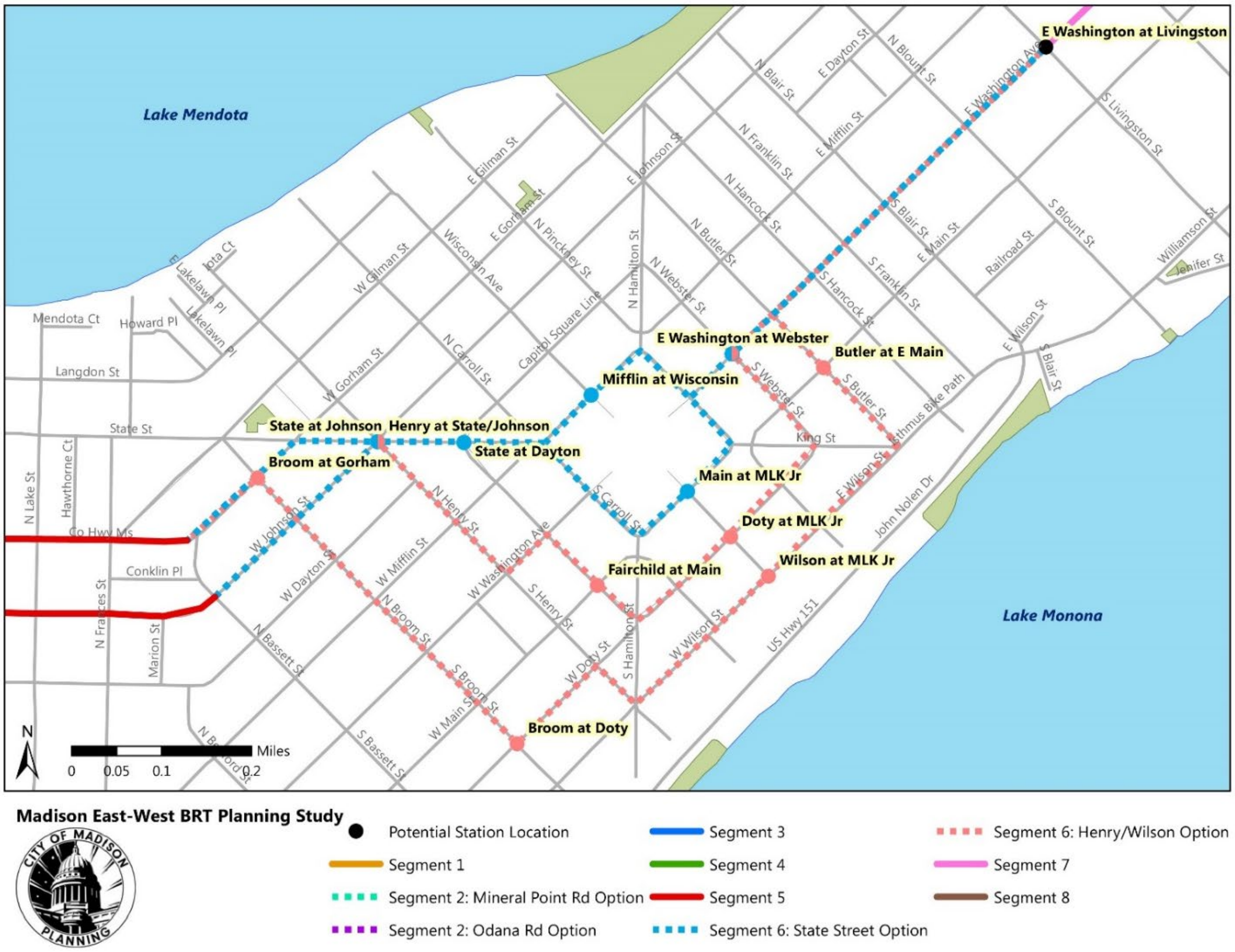


Table 2 lists the stations by segment. These are the stations included for the segment area analysis.

Table 2. Stations by Segment

Segment	Station Name
Segment 1	Mineral Point High Point
	Mineral Point at West Field
Segment 2: Odana	West Towne Mall
	Odana at Grand Canyon
	Odana at Research Park
	West Transfer Point

Segment	Station Name
Segment 2: MP	West Towne Mall
	Mineral Point at Yellowstone
	Mineral Point at Rosa
Segment 3	Mineral Point and Whitney Way
	Whitney Way and Sheboygan
	Sheboygan at Segoe
	University at Midvale
	University at Shorewood
Segment 4	University at University Bay / Farley
	Campus at Chamberlain (future)
Segment 5	University at Orchard
	Johnson at Orchard
	University at E Campus Mall
	Johnson at E Campus Mall
Segment 6: State St	State at Dayton
	Main at MLK Jr
	E Washington at Webster
	State at Johnson/Henry
	Mifflin at Wisconsin
Segment 6: Henry/Wilson	State at Johnson/Henry
	Fairchild at Main
	Doty at MLK Jr
	E Washington at Webster
	Butler at Main
	Wilson at MLK Jr
	Broom at Doty
	Broom at Gorham
Segment 7	E Washington at Livingston
	E Washington at Baldwin
	E Washington at S First
Segment 8	E Washington at 4th
	E Washington at Milwaukee
	E Washington at Marquette
	E Washington at Melvin
	Anderson at Madison College
	E Washington at Mendota
	E Washington at Thierer
	East Towne Mall

Station Siting

The BRT stations were initially laid out by MATPB staff in 2012 and have been adjusted and modified since. The goal was to space them out so that they are about a half mile apart. Several factors were considered:

1. **Physical site**
   There needs to be space for the BRT station; most of the time, BRT stations will end up where existing bus stops are.
2. **Ridership**
   BRT stations should minimize walk times and be close to ridership generators to the extent possible.
3. **Pedestrian infrastructure and crossings**
   Since BRT is mostly along arterial streets with higher traffic volumes and speeds, stations should be in places where people can cross, usually at traffic signals.
4. **Modal integration**
   Stations are placed where other bus routes intersect as well as where the street grid provides access to neighborhoods. Stations near the end of the line are in areas that could be served by park-and-ride lots.

The station locations identified resulted in about 50 station pairs for the full east-west, north-south system. In some locations, stations were closer together than ideal, but were placed to meet the criteria above. The current BRT study is looking closely at the station locations along the east-west corridor to continue to refine them.

Summary of Results

This section provides a brief summary of the station area analysis. The following sections provide a detailed analysis of each of the sub-criteria.

Parking Impacts

The number of parking spaces impacted by the proposed BRT will range from approximately 136 to nearly 500 spaces. The number of spaces is dependent on the type of runningway that will be selected for the LPA. The greatest impacts are along Segment 3 (Whitney Way), Segment 7 (E. Washington Ave), and Segment 8 (E. Washington Ave).

Traffic Impacts

The project team quantified traffic impacts associated with BRT using Synchro10 and SimTraffic 10 software by Trafficware, Inc. Key locations were selected to test the relative differences in traffic operations for general purpose motor vehicles and transit vehicles with varying levels of transit priority measures. These levels can generally be described as:

- Lower Level BRT Conditions: currently planned improvements with additional modest improvements made to provide a transit advantage including select intersection capacity expansion, bus bypass lanes to far side stops, and/or queue jump lanes with advanced bus (and in most cases right-turn) signal phases at some traffic signals. This generally corresponds to the Mixed Traffic and TSP alternative described in the other tech memos.

- Medium Level BRT Conditions: bus bypass lanes to far side stops, queue jump lanes with advanced bus signal phases at all traffic signals, and/or buses operating in an existing parking lane that has been converted to a bus lane (maintaining the same number of general purpose lanes and without substantial roadway widening). This is generally corresponds with the BAT Lane and TSP alternative in the other tech memos.
- Higher Level BRT Conditions: eliminate one existing general purpose travel lane in each direction by converting it to a new dedicated bus lane. This alternative was not evaluated in the other tech memos.

Table 3 and Table 4 show the results for the University Avenue corridor (Segoe Road to University Bay Drive/Farley Avenue) and East Washington Avenue corridor (Blair Street to Zaire Road), respectively.

Table 3. University Avenue Peak Hour Travel Times

Scenario	Cars		Buses	
Existing EB AM	5.1 min	--	6.5 min	--
Lower EB AM	4.0 min	(0.78x)	5.4 min	(0.83x)
Medium EB AM	4.1 min	(0.80x)	5.2 min	(0.80x)
Higher EB AM	11.2 min	**2.20x**	4.3 min	(0.66x)
Existing WB PM	4.7 min	--	6.2 min	--
Lower WB PM	4.1 min	(0.87x)	5.1 min	(0.82x)
Medium WB PM	5.0 min	1.06x	5.3 min[2]	(0.85x)
Higher WB PM	12.7 min	**2.70x**	4.3 min	(0.69x)
EB = eastbound, WB = westbound				

Table 4. East Washington Avenue Travel Times

Scenario	Cars		Buses	
Existing WB AM	13.6 mins	--	19.2 mins	--
Lower WB AM	14.3 mins	1.05x	18.3 mins	0.95x
Medium WB AM	13.7 mins	1.01x	13.8 mins	(0.72x)
Higher WB AM	18.9 mins	1.39x	14.1 mins[3]	(0.73x)
Existing EB PM	15.0 min	--	20.7 min	--
Lower EB PM	16.2 min	1.08x	17.9 min	(0.86x)
Medium EB PM	16.1 min	1.07x	16.2 min	(0.78x)

[2] WB Bus delay is higher in Medium than Low because the WB lane shift and GP lane drop at Midvale Boulevard causes severe congestion and queuing by cars that will delay the Buses from entering the WB Bus bypass lane to far side in-lane stop.

[3] WB AM peak hour Bus delay is modestly higher in the High than Medium condition because at many intersections the minimum bus delay is assumed to be 10 seconds when the adjacent General Purpose through delay is higher than 10 seconds. This occurs often in the High condition (2 GP lanes) but infrequently in the Medium condition (3 GP lanes).

Higher EB PM	33.1 min	**2.21x**	14.1 min	(0.68x)
WB = westbound, EB = eastbound				

Bicycle and Pedestrian Connectivity

Approximately half of the people living within a 10-minute bike ride of a station can access the station on low-stress routes. Large arterial streets and developments without gridded street networks limit both bicycle and pedestrian access to stations, particularly stations outside the central parts of Madison. Strategic investments in pedestrian and bicycle infrastructure near stations can significantly increase the number of people able to bike to the stations on low-stress routes. Providing short sidewalk or path segments that link nearby streets that do not otherwise connect can significantly boost station area access as can improvements to high-stress intersections and street crossings.

Parking Impacts

This section analyzed the potential impacts to on-street parking along the proposed BRT corridor.

Methodology

The methodology for assessing parking impacts included:

- Creating an inventory of existing on-street parking along the proposed route. Parking regulations and limits were documented on aerial imagery.
- Comparing the future build condition geometry with that of the existing condition to determine the approximate number of parking spaces impacted.

Assessed parking types included metered, unmetered and special use (i.e. taxi-only). If parking spaces were not officially designated, the number of parking spaces was estimated by performing a linear measurement of available curbside space in GIS and dividing it into 24-foot parking spaces. In areas where City of Madison street parking data did not account for parking restrictions near driveways or intersections, the following was assumed:

- 15-foot buffer of no parking around driveways; and
- 20-foot buffer of no parking around intersections.

Parking was assumed to be impacted if:

- A dedicated lane was proposed in place of parking;
- Parking within 650-feet on the approach to a queue jump intersection; or
- Parking within 50-feet after a queue jump intersection.

Parking utilization was NOT factored into the analysis; only parking availability is quantified.

Data Sources

Data sources used for determining existing parking inventory included:

- Google Earth aerial imagery
- Google Street View

- Field reviews conducted in May 2019 to confirm parking inventory
- City of Madison GIS data for metered and unmetered parking spaces

Summary of Results

On-street parking exists along the proposed route in the Tokay Boulevard, Whitney Way, Sheboygan Avenue, Capitol Square, and East Washington Avenue areas (Figure 4). These on-street parking areas consist of metered, unmetered, disabled, and various loading zones.

Figure 4. Existing On-street Parking

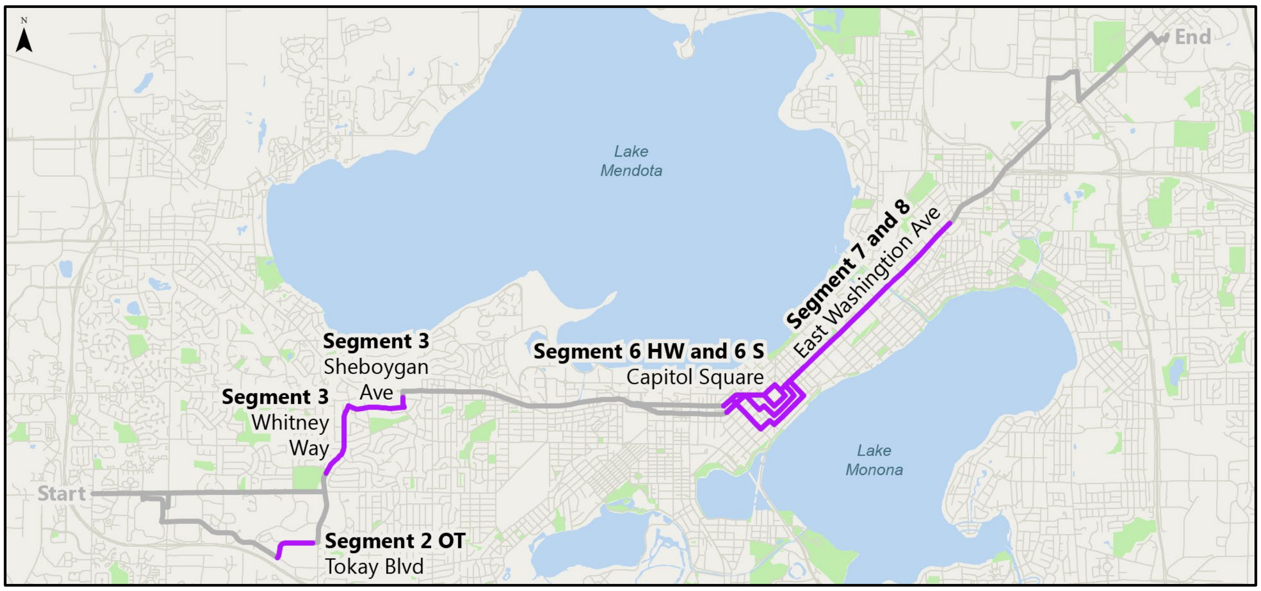


Table 5 and Table 6 lists the number of available parking spaces and number of parking spaces that would be impacted in each segment by the proposed alternatives.

- All on-street parking along East Washington Avenue (Segment 7 and 8) would be eliminated if dedicated lanes are the chosen runningway for the LPA.
- All on-street parking along Whitney Way (Segment 3) would be eliminated if dedicated lanes are the chosen runningway for the LPA.
- On-street parking in the Capitol Square area (Segment 6) is largely unimpacted by the proposed routes, except for a few spaces where a dedicated bus lane is proposed along East Washington Avenue.
- For the queue jump operating option, parking would only be removed on the approach to the stop and immediately after the stop on the far-side of the intersection.

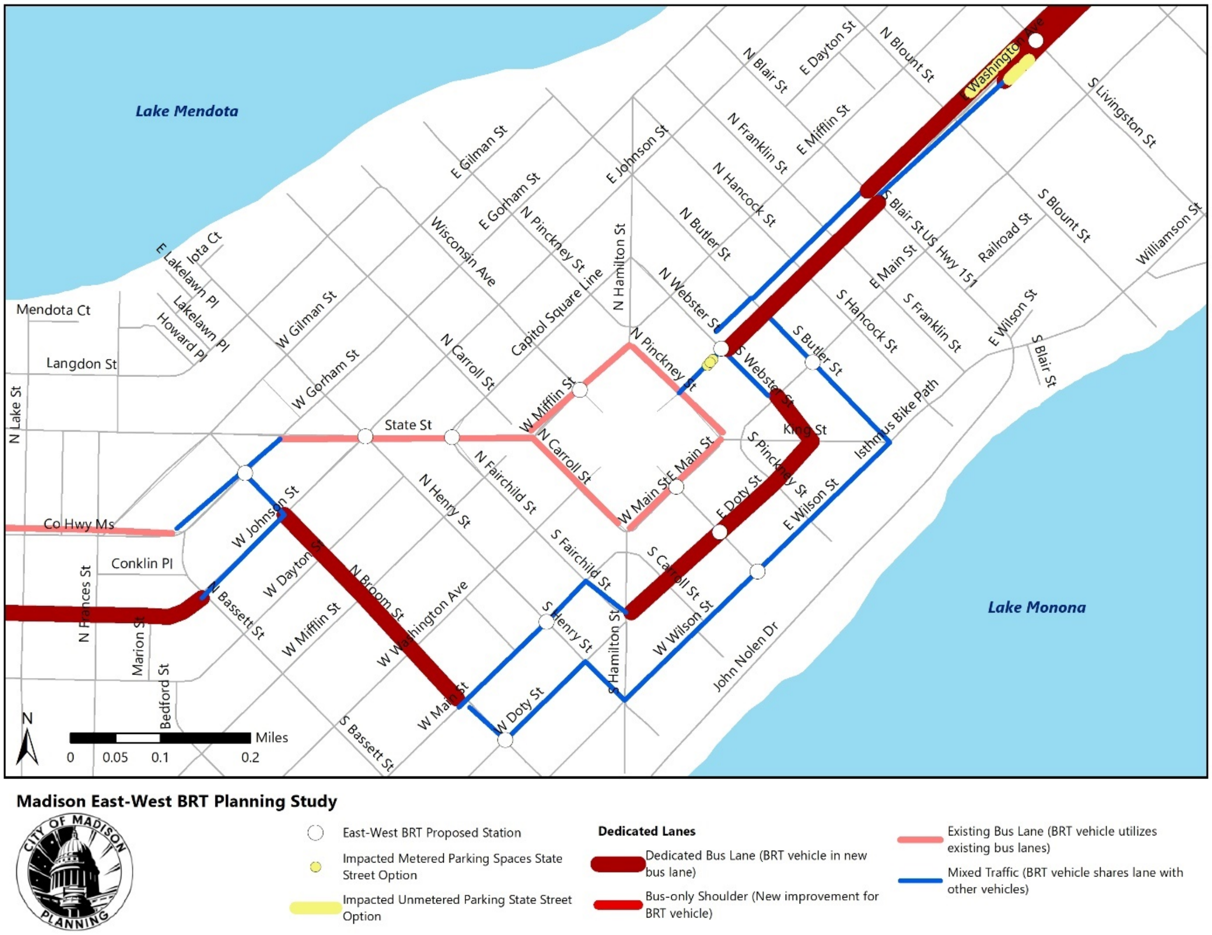
Table 5. On-street Parking Impacts by Segment

Proposed Segments	Street Parking (spaces)						Loading Zones			
	Metered		Unmetered			ADA	Freight / Trucks	Passenger		
	Existing	Impacted (DL)	Existing	Impacted (DL)	Impacted (QJ)	Existing	Existing	Existing	Impacted (DL)	Impacted (QJ)
Seg 1	-	-	-	-	-	-	-	-	-	-
Seg 2MP	-	-	-	-	-	-	-	-	-	-
Seg 2OT	-	-	47	-	-	-	-	-	-	-
Seg 3	-	-	243	146	4	-	-	2	-	-
Seg 4	-	-	-	-	-	-	-	-	-	-
Seg 5	-	-	-	-	-	-	-	-	-	-
Seg 6HW	292	89	58	17	-	3	24	9	1	-
Seg 6S	99	3	101	7	-	5	7	2	-	-
Seg 7	-	-	204	204	94	-	-	2	2	2
Seg 8	-	-	56	10	38	-	-	-	-	-
Total	**391**	**92**	**709**	**384**	**136**	**8**	**31**	**15**	**1**	**2**

Notes: DL stands for dedicated lane. QJ stands for queue jump.

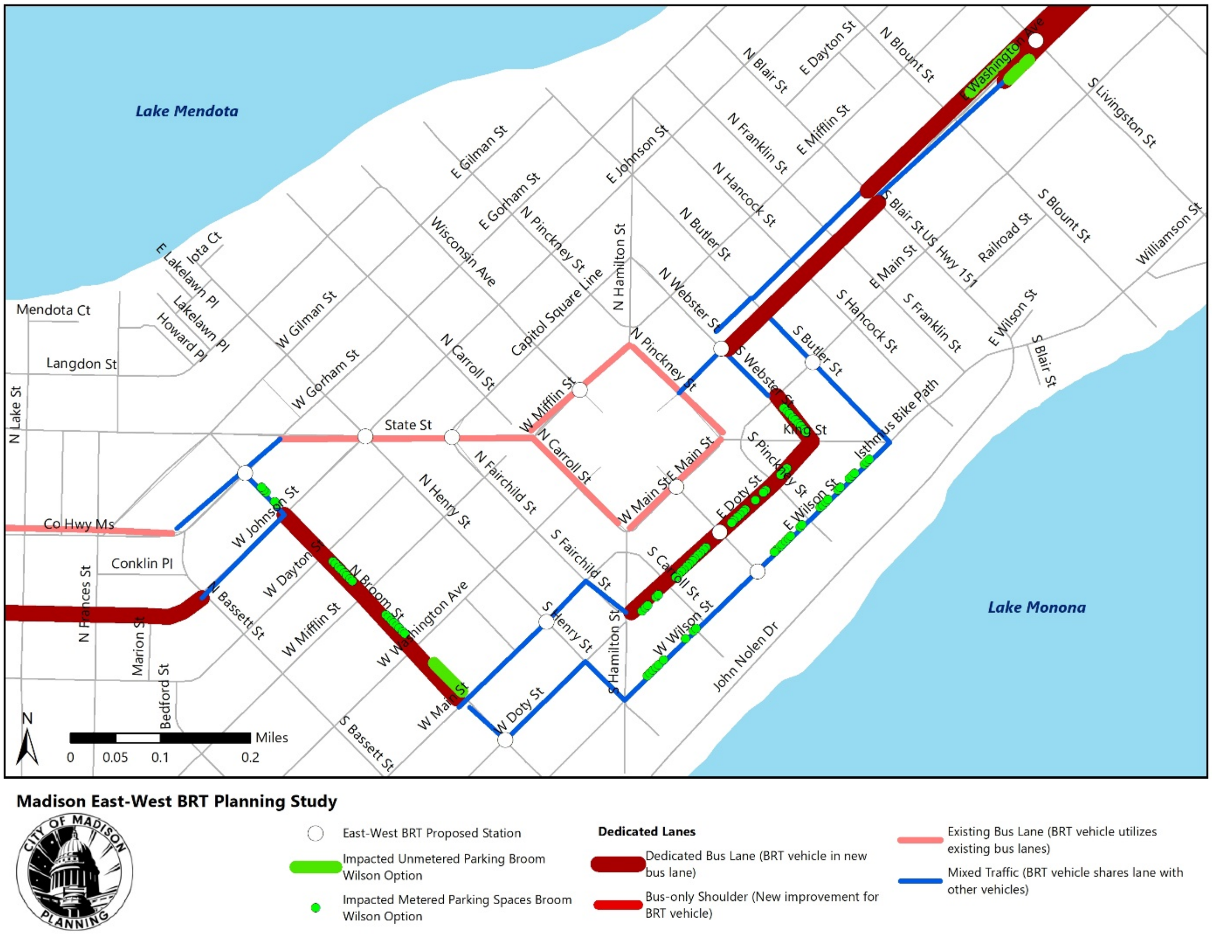
Figure 5and Figure 6 show the locations of parking impacts for the two options for Segment 6.

Figure 5. Parking Impacts for Segment 6 State Street Option



Source: City of Madison

Figure 6. Parking Impacts for Segment 6 Broom/Wilson Option



Source: City of Madison

Figure 7 shows examples of on-street parking throughout the BRT corridor.

Figure 7. Examples of Existing On-street Parking

Capitol Square

East Washington Avenue

Traffic Impacts

Potential traffic impacts from the proposed BRT were analyzed in this section.

Methodology

The project team quantified traffic impacts associated with BRT using Synchro10 and SimTraffic 10 software by Trafficware, Inc. Key locations were selected to test the relative differences in traffic operations for general purpose motor vehicles and transit vehicles with varying levels of transit priority measures. These levels can generally be described as:

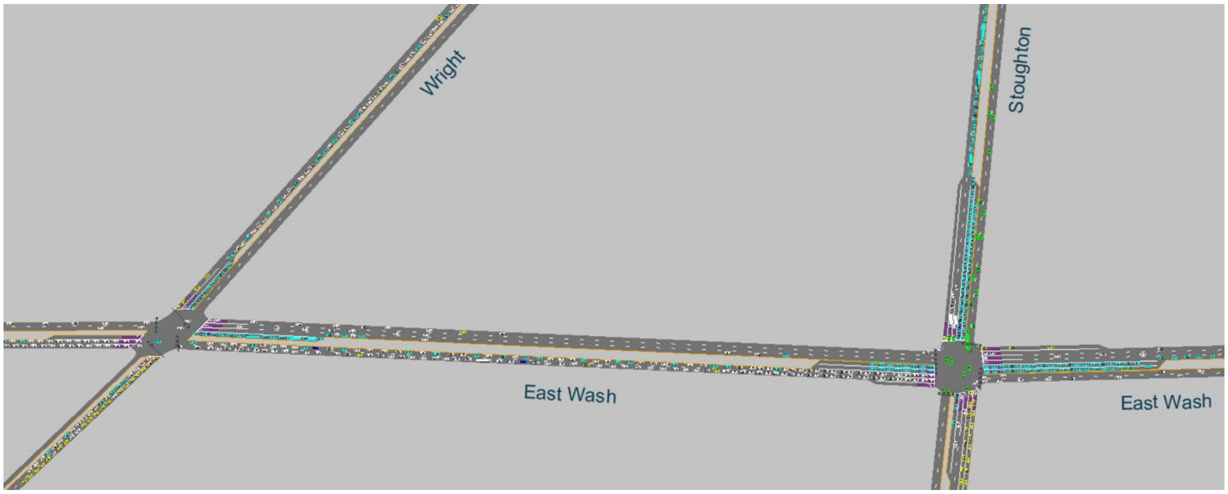
- Lower Level BRT Conditions: currently planned improvements with additional modest improvements made to provide a transit advantage including select intersection capacity expansion, bus bypass lanes to far side stops, and/or queue jump lanes with advanced bus (and in most cases right-turn) signal phases at some traffic signals. This generally corresponds to the Mixed Traffic and TSP alternative described in the other tech memos.
- Medium Level BRT Conditions: bus bypass lanes to far side stops, queue jump lanes with advanced bus signal phases at all traffic signals, and/or buses operating in an existing parking lane that has been converted to a bus lane (maintaining the same number of general purpose lanes and without substantial roadway widening). This generally corresponds with the Bus Lane and TSP alternative in the other tech memos.
- Higher Level BRT Conditions: eliminate one existing general purpose travel lane in each direction by converting it to a new dedicated bus lane. This alternative was not evaluated in the other tech memos.

The traffic operations impacts were compared based on the predicted delays and queue lengths from Synchro10. The team also used SimTraffic 10 simulation modeling to confirm the Synchro output and to visually observe how operating conditions could be expected to vary under the various conditions. In addition to the queuing and delays (and associated Levels of Service[4] in the peak directions), the team also estimated travel times for general purpose motor vehicles and for buses. Finally, the amount of demand reduction[5] that would be needed to mitigate negative impacts and result in operations for general purpose motor vehicles remaining similar to existing conditions was estimated for the Lower, Medium, and Higher BRT Conditions.

[4] The Transportation Research Board's Highway Capacity Manual HCM defines intersection operations in terms of Level of Service (LOS), which is a measure of traffic flow and delay conditions. LOS is a quantitative measure that can be described using the letter grades, "A" through "F" with LOS A representing the best conditions and lowest delay, and LOS F representing the worst conditions and significant delays and congestion.

[5] The demand reduction could take the form of drivers traveling at different times, taking different routes, and/or selecting a different mode such as walking, bicycling, or using transit.

Figure 8. SimTraffic Simulation Modeling of Higher BRT Conditions on East Washington Avenue



Data Sources

The locations where the team completed detailed operations analysis were selected based on available data and their importance to operating conditions along the East-West BRT Route. The City of Madison provided Synchro10 models of two key portions of the corridor: University Avenue from Shorewood Boulevard to University Bay Drive/Farley Avenue; and East Washington Avenue from Blair Street to East Towne Mall. These models included existing peak period turning movement volumes, roadway configurations, intersection layouts, and traffic signal timing and phasing data. The project team made some adjustments to the City models including:

1. University Avenue Corridor
    a. Added the signalized intersections of:
        i. Segoe Road
        ii. Hilldale Way
        iii. Midvale Boulevard
    b. Modified the SimTraffic simulation settings for a longer seed time and simulation period given the size of the models and degree of congestion in some conditions.
2. East Washington Avenue Corridor

Modified the SimTraffic simulation settings for a longer seed time and simulation period given the size of the models and degree of congestion in some conditions.

Summary of Results

1. University Avenue Corridor

The operational modifications in the models generally include:

- Lower BRT Level: planned improvements at University Bay Drive/Farley Avenue only[6].
- Medium BRT Level: Lower level plus bus bypass lanes to far side stops at Midvale Boulevard.
- Higher BRT Investment Level: Lower level plus one general purpose (GP) car/truck lane converted to a Bus Lane[7] in each direction.

Intersection by intersection changes for each scenario are provided in Table 6.

Table 6. University Avenue Operational Modifications for the Traffic Analysis

University Avenue Intersection	Lower BRT Scenario	Medium BRT Scenario	Higher BRT Scenario
Segoe Road	No Change	NBR/WBL advanced/extended green for BRT	Same as Medium
Hilldale Way	No Change	No Change	EB and WB Bus Lanes (one fewer GP lane)
Midvale Boulevard	No Change	EB: Right-turn/Bus bypass lane to far side pullout stop WB: GP lane shift, drop one GP as WBL, curb Bus bypass lane to far side in-lane stop	EB and WB Bus Lanes (one fewer GP lane)
Shorewood Boulevard	No Change	No Change	EB and WB Bus Lanes (one fewer GP lane)
University Bay Drive/ Farley Avenue	EB: far side pullout stop, dual EBL WB: Bus bypass lane to far side pullout stop	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
NBR = northbound right-turn, WBL = westbound left-turn, EB = eastbound, WB = westbound, EBL = eastbound left-turn			

The travel time comparisons provide an estimate of traffic conditions with the various BRT scenarios versus existing traffic conditions according to the models. The University Avenue travel times are from Segoe Road (not including the intersection delay) through the University Bay Drive/Farley Avenue intersection (including the intersection delay). The travel time results are summarized in Table 7.

Table 7. University Avenue Peak Hour Travel Times

Scenario	Cars		Buses	
Existing EB AM	5.1 min	--	6.5 min	--

[6] Planned improvements are in design for the University Avenue corridor from east of Shorewood Boulevard through the University Bay Drive/Farley Avenue intersection. These include the addition of a dual eastbound left-turn bay, an eastbound far side pullout bus stop, and the addition of a westbound right-turn only/bus bypass lane to the existing far side pull out bus stop .

[7] The Bus Lanes would allow buses and right-turning cars and trucks and may or may not allow bicycles. The existing diamond lanes on Mineral Point Road (and some other Madison streets) are Bus Lanes.

Scenario	Cars		Buses	
Lower EB AM	4.1 min	(0.80x)	5.5 min	(0.86x)
Medium EB AM	4.1 min	(0.80x)	5.2 min	(0.80x)
Higher EB AM	11.2 min	**2.17x**	4.3 min	(0.67x)
Existing WB PM	4.7 min	--	6.2 min	--
Lower WB PM	4.1 min	(0.87x)	5.1 min	(0.83x)
Medium WB PM	5.0 min	1.08x	5.3 min[8]	(0.85x)
Higher WB PM	12.7 min	**2.71x**	4.3 min	(0.70x)
EB = eastbound, WB = westbound				

The project team also evaluated vehicle queueing (or the length of backups at the traffic signals) for each BRT scenario and existing conditions based on the traffic models. The queuing results are summarized in Table 8. The blocks along University Avenue in this area are generally about 600 to 700-feet in length.

Table 8. University Avenue Average Vehicle Peak Hour Queuing

Scenario	Intersections with Avg. Through Queues >500 feet		Intersections with Avg. Through Queues >1,000 feet	
Existing EB AM	4 of 5	80%	0 of 5	0%
Lower EB AM	2 of 5	40%	0 of 5	0%
Medium EB AM	2 of 5	40%	0 of 5	0%
Higher EB AM	5 of 5	100%	5 of 5	100%
Existing WB PM	2 of 5	40%	0 of 5	0%
Lower WB PM	2 of 5	40%	0 of 5	0%
Medium WB PM	2 of 5	40%	0 of 5	0%
Higher WB PM	4 of 5	80%	4 of 5	80%
EB = eastbound, WB = westbound				

The final metric the project team evaluated is the reduction in general purpose car and truck trips that would be needed during the peak hours in order to maintain conditions that are similar to the existing conditions. This reduced demand would need to change modes (switch to walking, biking, or taking the bus), change when they drive, or change the route they drive. The results for University Avenue are summarized below:

- AM Medium BRT: about 15 percent, or 300 to 400 eastbound vehicles during the morning rush hour.
- AM Higher BRT: about 30 percent, or 650 to 700 eastbound vehicles during the morning rush hour.
- PM Medium BRT: about 25 percent, or 560 westbound vehicles during the afternoon rush hour.

[8] WB Bus delay is higher in Medium than Low because the WB lane shift and GP lane drop at Midvale Boulevard causes severe congestion and queuing by cars that will delay the Buses from entering the WB Bus bypass lane to far side in-lane stop.

- PM Higher BRT: about 30 percent, or 650 to 810 westbound vehicles during the afternoon rush hour.

2. East Washington Avenue Corridor

The operational modifications in the models include:

- Lower BRT Level: Queue jumps or bus bypass lanes to far side stops only. Maintains the existing number of eastbound and westbound general purpose car/truck lanes. Requires parking restrictions near the signalized intersections.
- Medium BRT Level: Eastbound and westbound curb parking lanes converted to Bus Lanes (same number of general purpose lanes in each direction) west of Milwaukee Street. Queue jumps or bus bypass lanes assumed east of Milwaukee Street (same as Lower BRT Level).
- Higher BRT Investment Level: One general purpose lane converted to a Bus Lane in each direction.

Intersection by intersection changes for each scenario are provided in Table 9.

Table 9. East Washington Avenue Operational Modifications for the Traffic Analysis

E Washington Avenue Intersection	Lower BRT Scenario	Medium BRT Scenario	Higher BRT Scenario
Blair Street	EB and WB add queue jump.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Livingston Street	EB and WB bus bypass lanes to far side pullout stops in existing curb parking lanes.	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)
Paterson Street	EB and WB queue jumps in existing curb parking lanes.	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)
Ingersoll Street	EB and WB queue jumps in existing curb parking lanes.	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)
Baldwin Street	EB and WB bus bypass lanes to far side pullout stops in existing curb parking lanes.	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)
First Street	EB and WB bus bypass lanes to far side pullout stops in existing curb parking lanes.	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)
Fourth Street	EB and WB bus bypass lanes to far side pullout stops in existing curb parking lanes.	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)
Milwaukee Street	EB and WB bus bypass lanes to far side pullout	EB and WB Bus Lanes in existing curb parking lanes.	EB and WB Bus Lanes (one fewer GP lane)

E Washington Avenue Intersection	Lower BRT Scenario	Medium BRT Scenario	Higher BRT Scenario
	stops in existing curb parking lanes.		
Johnson Street	EB: add queue jump. WB: queue jump in right-turn lane.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Marquette Street	EB: bus bypass to far side stop in curb area. WB: bus bypass to far side stop in existing curb parking lane.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Eastbound WIS 30 Ramps	EB and WB add queue jump.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Westbound WIS 30 Ramps	EB: mixed traffic. WB: queue jump in right-turn lane.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Wright Street/ Fair Oaks Avenue	EB: advanced/ extended EBL signal. SB/WB: mixed traffic.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Stoughton Road	SBL: advanced BRT left-turn from the SB right-turn lane. WBR: mixed traffic.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Mendota Street	EB and WB add bus bypasses and far side pullout stops.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Lien Road	EB queue jump in right-turn lane. WB: add queue jump.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Portage Road/ Thierer Road	EB and WB bus bypasses in right-turn lanes and add far side pullout stops.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Continental Lane/ Eagan Road	EB and WB mixed traffic.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)
Zeier Road	EBR and NBL mixed traffic advanced/ extended signal.	Same as Low	EB and WB Bus Lanes (one fewer GP lane)

EB = eastbound, WB = westbound, EBL = eastbound left-turn, SB = southbound, SBR = southbound right-turn, SBL = southbound left-turn, WBR = westbound right-turn, NBL = northbound left-turn, NB = northbound

The travel time comparisons provide an estimate of traffic conditions with the various BRT scenarios versus existing traffic conditions according to the models. The East Washington Avenue travel times are from Blair Street through the Zeier Road intersection. The base freeflow travel time does not include the Wright Street to Anderson Street to Stoughton Road to East Washington Avenue portion of the route (serving Madison College). Delay calculations include turning movement delays at Wright Street/East

Washington Avenue and Stoughton Road/East Washington Avenue but not at Wright Street/Anderson Street or Anderson Street/Stoughton Road. BRT station delays include the Madison College stop. The travel time results are summarized in Table 10.

Table 10. East Washington Avenue Travel Times

Scenario	Cars		Buses	
Existing WB AM	13.4 mins	--	19.0 mins	--
Lower WB AM	11.2 mins	(0.83x)	15.6 mins	(0.82x)
Medium WB AM	13.4 mins	1.00x	13.9 mins	(0.73x)
Higher WB AM	18.9 mins	1.41x	14.1 mins[9]	(0.74x)
Existing EB PM	15.0 min	--	20.7 min	--
Lower EB PM	13.5 min	0.90x	16.5 min	(0.80x)
Medium EB PM	13.5 min	0.90x	15.2 min	(0.74x)
Higher EB PM	35.4 min	**2.36x**	14.2 min	(0.69x)
WB = westbound, EB = eastbound				

The project team also evaluated vehicle queueing (or the length of backups at the traffic signals) for each BRT scenario and existing conditions based on the traffic models. The queuing results are summarized in Table 11. The blocks along East Washington Avenue in this area are generally 660-feet in length, and about every other intersection is signalized (with some exceptions).

Table 11. East Washington Avenue Vehicle Queuing

Scenario	Intersections with Avg. Through Queues >500 feet		Intersections with Avg. Through Queues >1,000 feet	
Existing WB AM	2 of 19	11%	0 of 19	0%
Lower WB AM	2 of 19	11%	0 of 19	0%
Medium WB AM	2 of 19	11%	0 of 19	0%
Higher WB AM	8 of 19	42%	7 of 19	37%
Existing EB PM	5 of 19	26%	0 of 19	0%
Lower EB PM	8 of 19	42%	0 of 19	0%
Medium EB PM	5 of 19	26%	0 of 19	0%
Higher EB PM	13 of 19	68%	10 of 19	52%
WB = westbound, EB = eastbound				

[9] WB AM peak hour Bus delay is slightly higher in the High than Medium condition because at many intersections the minimum bus delay is assumed to be 10 seconds when the adjacent General Purpose through delay is higher than 10 seconds. This occurs often in the High condition (2 GP lanes) but in the Medium condition (3 GP lanes) the adjacent through lane frequently has delay lower than 10 seconds, so the buses do too.

The final metric the project team evaluated is the reduction in car trips that would be needed during the peak hours in order to maintain conditions for general purpose cars and trucks that are similar to the existing conditions. This reduced demand would need to change modes (switch to walking, biking, or taking the bus), change when they drive, or change the route they drive. The results for East Washington Avenue are summarized below:

- AM Medium: NA.
- AM High[10]: about 15 percent, or 350 to 400 vehicles westbound/inbound during the morning rush hour.
- PM Medium: NA.
- PM High[11]: about 15 percent, or 390 to 450 vehicles eastbound/outbound during the afternoon rush hour.

Because removing a travel lane on East Washington Ave. and University would result in substantial gridlock and travel times for autos being increased by over two times, the alternative that would convert one general purpose lane to a bus lane was removed from further consideration.

Bicycle and Pedestrian Connectivity

The vast majority of transit users arrive at stations or stops on foot, with a smaller number arriving by bike. At select stations, some users may drive to stations to utilize park-and-ride lots or nearby street parking, but even in those cases they must walk to the actual station. For transit stations to be usable, transit users must have safe and comfortable walking and bicycling routes to the stations.

Populations within walking distance of transit stations are typically measured using circular catchments of constant radius. The effects of the street network are either assumed to be negligible or they are indirectly approximated based on easily measured metrics such as the total length of roadway within the circular catchment. Bicycle access is often not quantified at all. Circular catchment areas would be expected to provide good approximations of the actual area that can be easily accessed on foot or by bicycle if the street and path network is well connected and uniform in all directions. However, in areas that include many discontinuities in the street network, especially suburban areas, this methodology can break down. Methods that take these discontinuities into account are therefore necessary to accurately assess pedestrian and bicycle access to potential transit stations.

Methodology

To achieve a more nuanced understanding of the areas accessible on foot and by bicycle from potential transit stations, this analysis will map areas within specific distances of each station location while also accounting for the connectivity of the pedestrian and bicycle networks within those areas.

The pedestrian catchment areas, or "walk sheds," will map the area within a half- mile walk of each station, which represents approximately a 10-minute walk at average walking speeds (3 mph). The bicycle catchment areas, or "bike sheds," will identify areas within a 1.66-mile bike ride of each station, again

[10] Based on operations at the First Street intersection.
[11] Based on operations at the Milwaukee Street intersection.

representing a 10-minute bike ride at average speeds (10 mph). Because bicycle and pedestrian network connectivity is accounted for in the analysis, this method will result in catchment areas that extend farther where connectivity is good and extend less far where circuitous routes are required. The catchment areas are not simple circles around each station like what is produced by the simplistic analyses described above.

Bicycle catchment areas will be further refined by identifying the portion of these potential catchment areas where appealing low-stress route options are available. "Low-stress" streets will be identified using the Madison Area MPO's "level of traffic stress" categorization system (Table 12) and selecting routes using only segments rated as LTS 1 or LTS 2.

Table 12. Level of Traffic Stress Scoring

TRAFFIC STRESS RATING	INTERPRETATION
LTS 1	Appropriate for all ages and abilities
LTS 2	Comfortable for a typical adult
LTS 3	Tolerable for an experienced bicyclist
LTS 4	Highly stressful

Finally, block-level census population counts will be used to estimate the population living within each of the catchment areas.

Walking and Bicycling Network Definition

For this analysis all streets, except freeways, will be assumed to allow pedestrian travel even if pedestrian facilities are lacking (sidewalks, marked crosswalks, etc.) or do not meet accessibility standards. All streets, except freeways, will also be assumed to allow bicycle travel; bicycle riders are assumed to share a lane with motor vehicles if no bicycle facilities (bicycle lanes or shared-use paths) are present. The results will be based on existing network conditions and in many cases will highlight where pedestrian and bicycle connectivity improvements could result in creating larger catchment areas and more people being able to use active transportation to access stations.

Data Sources

- Street network, traffic volume, and speed limit data compiled from Esri, City of Madison, and OpenStreetMap.
- Bikeway network data from the City of Madison
- Bicycle Level of Traffic Stress from the Madison Area MPO
- Population data from the US Census Bureau

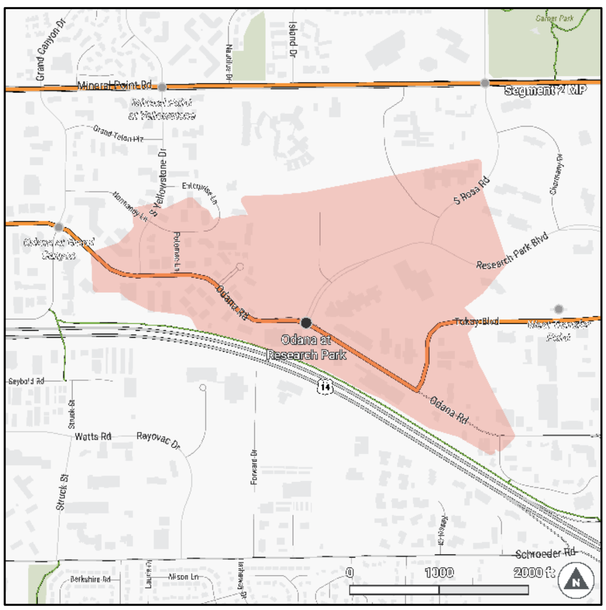
Summary of Results

The results of the analysis are displayed on a series of maps in Appendix A. One map is provided for each station location for the half-mile walk shed and for the 1.66-mile bike shed. Because stations are generally spaced closer than every half-mile, particularly on the isthmus, the walk and bike sheds for each station often overlap with the walk and bike sheds from adjacent stations, although this is not shown on the maps. Potential BRT users in the overlap areas have a choice as to which station is more accessible to them.

Walk Sheds

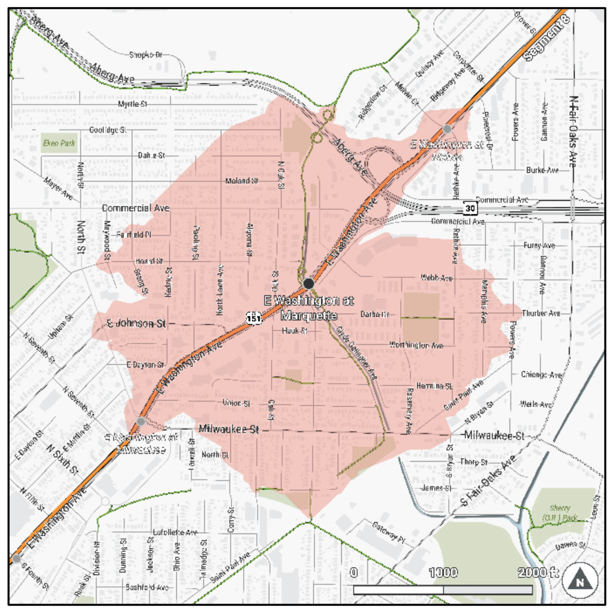
The half-mile walk sheds calculated around each potential station vary in shape based on the connectivity of the local street network. Areas of the city with a well-connected street grid provide walking access to nearly all areas within a half-mile radius of the station location. The walk sheds in areas of the city with less connected streets, or with major barriers like the Beltline, highlight that locations physically near a station may still be inaccessible to people walking. Figure 9 displays the walk shed for the Odana/Research Park station. At this location, the Beltline and a circuitous street network limit the area that is within a half-mile walk of the station. In contrast, Figure 10 displays the walk shed around the East Washington/Marquette station where nearly every point within a half-mile radius of the station is accessible on foot. Strategic investments in pedestrian infrastructure such as short path or sidewalk segments connecting disconnected street grids or crossing major barriers can significantly increase access to some of the station locations.

Figure 9. Odana/Research Park Walk Shed



The half-mile walk shed around the Odana / Research Park station demonstrates how the Beltline and a curvilinear street pattern limit the station area access.

Figure 10. East Washington/Marquette Walk Shed



The half-mile walk shed around the East Washington / Marquette station encompasses most areas within one mile of the station due to the well-connected street network.

Bike Sheds

The bike shed analysis maps display two distinct bike sheds for each station location: the 1.66-mile bike shed using all available streets and paths (the "potential" bike shed), and overlaid on that, the 1.66-mile bike shed using only streets and paths that present a low level of traffic stress (LTS 1 or 2) for people bicycling (the "low-stress" bike shed). The potential bike sheds are relatively similar in shape and generally encompass most areas within 1.66-miles of each potential BRT station. However, the low-stress bike sheds vary dramatically, with a number of station locations not having any low-stress bicycle access. Figure 11 and Figure 12 display station locations on the isthmus that are only one block apart; while both stations effectively serve the entire isthmus within the full 1.66-mile bike shed, one of the station locations is not accessible at all using low-stress streets because the blocks immediately surrounding the station are not low-stress. In locations where the low-stress bike sheds are large, low-stress routes to stations are sometimes convoluted and longer than the shortest possible routes. The low-stress bike sheds demonstrate where investments in high quality bicycle infrastructure can improve access to stations by people bicycling.

Figure 11. Full Bike Shed

The full bike shed (light purple) and the low-stress bike shed (dark purple) are nearly contiguous for the Butler / East Main station.

Figure 12. Low-Stress Bike Shed

The East Washington / Webster station is not served by any low-stress routes despite being only one block from the station in Figure 11.

Population Coverage

Table 13 contains a complete listing of the populations within each shed by station. The population figures are useful when comparing two or more alternatives for a station location or corridor. The population figures were calculated using US Census block groups. A calculation was performed based on how much of the block group was covered by the output shed. For example, if 75 percent of the block group's area was within the shed, we multiplied the total population of the block group by 75 percent.

This was applied to all block groups that were within each station's shed, and then the results were summed for the shed in total.

Table 13: Approximate population within each walk and bike shed by BRT planning segment

ID	Station Location	Segment	Population 0.5 Mile Walk Shed	Population 1.66 Mile Bike Shed	Population 1.66 Mile Low Stress Bike Shed	% of Full Bike Shed Population within the Low Stress Bike Shed
1	Mineral Point at High Point	1	2,311	16,086	-	0%
2	Mineral Point at Westfield	1	1,838	17,304	8,536	49%
3	West Towne Mall	2OT	1,205	17,371	-	0%
4	Odana at Grand Canyon	2OT	811	16,199	3,258	20%
5	Odana at Research Park	2OT	341	11,704	511	4%
6	West Transfer Point	2OT	598	13,691	464	3%
7	Mineral Point at Yellowstone	2MP	1,457	14,652	-	0%
8	Mineral Point at Rosa Rd	2MP	1,040	15,447	531	3%
9	Mineral Point and Whitney Way	3	1,468	18,231	-	0%
10	Whitney Way and Sheboygan	3	2,650	17,548	9,285	53%
11	Sheboygan at Segoe	3	3,053	19,665	-	0%
12	University at Midvale	3	2,448	22,656	12,821	57%
13	University at Shorewood	3	2,258	24,397	16,175	66%
14	University at University Bay	4	3,277	30,510	13,098	43%
15	Campus at Chamberlain (future)	4	3,939	46,962	22,074	47%
16	University at Orchard	5	8,211	54,071	41,798	77%
17	University at E. Campus Mall	5	16,437	53,277	46,855	88%
18	Johnson at Orchard	5	9,254	54,031	44,283	82%
19	Johnson at E. Campus Mall	5	16,248	53,815	46,973	87%
20	Broom at Gorham	6HW	19,927	49,781	-	0%
21	State at Johnson	6S	18,679	48,867	42,064	86%
22	State at Dayton	6S	16,961	48,274	41,126	85%
23	Mifflin at Wisconsin	6S	12,791	46,720	40,455	87%
24	Broom at Doty	6HW	9,439	47,876	34,993	73%
25	Fairchild at Main	6HW	10,358	46,738	37,826	81%
26	Main at MLK Jr	6S	8,256	45,633	39,642	87%
27	Doty at MLK Jr	6HW	6,415	44,594	37,979	85%
28	Wilson at MLK Jr	6HW	5,258	43,363	-	0%
29	E Washington at Webster	6S/6HW	7,677	44,055	-	0%
30	Butler at E Main	6HW	6,535	42,953	37,550	87%
31	E Washington at Livingston	7	4,534	41,101	26,753	65%
32	E Washington at Baldwin	7	3,753	26,894	-	0%
33	E Washington at First	7	3,321	24,202	-	0%
34	E Washington at 4th	8	2,915	22,871	16,184	71%
35	E Washington at Milwaukee	8	3,214	22,835	11,516	50%
36	E Washington at Marquette	8	2,798	18,733	13,622	73%
37	E Washington at Melvin	8	935	16,181	-	0%

ID	Station Location	Segment	Population 0.5 Mile Walk Shed	Population 1.66 Mile Bike Shed	Population 1.66 Mile Low Stress Bike Shed	% of Full Bike Shed Population within the Low Stress Bike Shed
38	Anderson at Madison College	8	316	9,527	112	1%
39	E Washington at Mendota	8	763	10,496	1,853	18%
40	E Washington at Thierer	8	1,031	10,766	-	0%
41	East Towne Mall	8	1,121	9,009	163	2%

About half of the people living within a 10-minute bike ride of a station can access the station on low-stress routes. The segments at each end of the BRT corridor (1, 2MP, 2OT, 7, and 8) all have relatively low access using the low-stress bicycle network. This is due to several factors including the prevalence of larger, higher stress streets, the lack of a gridded street network in areas surrounding the stations, and a less robust network of bicycle facilities than in more central portions of the city. Strategic investments in bicycle infrastructure near stations or adjustments in station locations can significantly increase the number of people able to bike to the stations on low-stress routes.