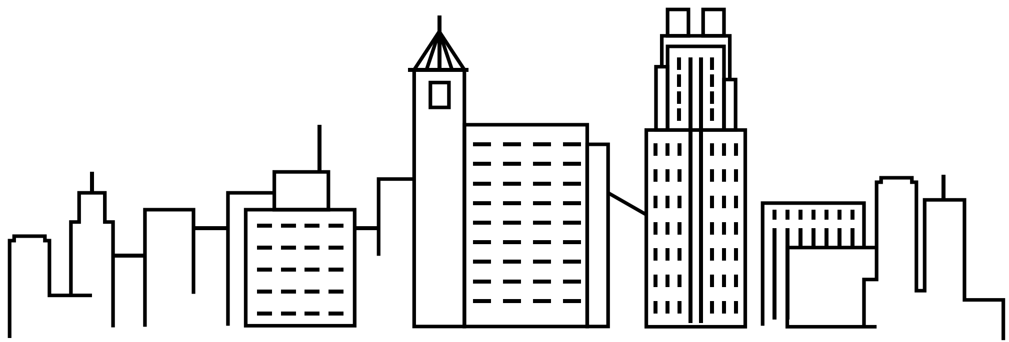
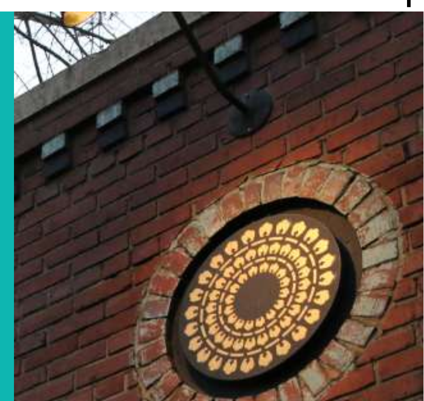
Raleigh Downtown **Transportation Plan**

VOLUME 3: IMPLEMENTATION PLAN

June 2019





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1.0 Introduction

A cross-departmental, multi-agency team including the City of Raleigh, CAMPO, GoTriangle, and NCDOT along with input from the Advisory Committee, Stakeholder Groups, and the public have all contributed in the development of the final recommendations for a phased implementation plan of the proposed Bus Rapid Transit (BRT) corridors, a proposed bicycle network and a streetscape framework for Downtown Raleigh. These elements combined make up the Raleigh Downtown Transportation Plan.

The Executive Summary (under separate cover) was developed as a high-level overview of the 15-month process, the subsequent recommendations and the next steps for implementing the plan. This Implementation Plan report provides a more detailed description of those final recommendations, key considerations regarding each of the recommendations and proposed phasing of the projects as well as anticipated next steps for implementation. It should be noted that the proposed BRT projects currently have an identified local funding source through the Wake Transit ½ cent sales tax that was approved by voters in 2016 and are anticipated to receive federal funding as well the Federal Transit Administration (FTA) Capital Improvements Grants (CIG) Small Starts Program. The bicycle recommendations do not currently have funding identified and will need to be coordinated with the City's Capital Improvement Program (CIP).

The Raleigh Downtown Transportation Plan focused on the importance of tradeoffs and how to balance these in a Downtown setting. Due to the limited right-of-way width with in Downtown, typically around 66-feet wide from building face to building face, it was determined that streets should be assigned a modal priority so that all modes can be accommodated with high-quality facilities. Implementation of the high-quality facilities will have impacts on certain other facilities in the limited right-of-way as well and therein lies the tradeoff. As described in the Scenario Evaluation Report (Volume II), street typical sections have been developed for the BRT corridors which require removal of existing on-street parking and loading zone spaces to accommodate the exclusive BRT lanes. For each phase of the BRT and bicycle network implementation, the assumed on-street parking/loading zone impacts have been calculated and are shown in each section of this report.

2.0 Bus Rapid Transit (BRT) Phasing Strategy

BRT recommendations are organized around three timeframes:

- Near-term (revenue service as early as 2023)
- Mid-term (revenue service as early as 2025)
- Full build-out (revenue service as early as 2027)

These recommendations are based on the assumption that the eastern BRT corridor (New Bern Avenue) will be operational first, the western and southern corridors will be operational next, and that the northern BRT corridor will be operational last. Another key assumption is that BRT is assumed to operate in exclusive BRT lanes everywhere within Downtown. Although design has not been completed for the BRT corridors, it is understood that exclusive BRT lanes in Downtown will provide the most efficient and reliable transit service and should be utilized to the greatest extent feasible, ecially in Downtown where transit signal priority (TSP) may only provide limited benefits due to the high number of traffic signals present. Exclusive BRT lanes in Downtown was established as the starting design assumption and it will need to be further assessed during Project Development and preliminary design to confirm that exclusive lanes are feasible throughout Downtown.

Table 1 provides planning level cost estimates for the near-term and mid-term BRT phases. Cost estimates were not developed for the full build-out phase because the preferred BRT alignment has not been selected. These costs were developed using the New Bern Avenue BRT cost per mile estimates developed for the Major Investment Study (MIS) completed by CAMPO for the four proposed BRT corridors in 2018. These costs are in 2017 dollars and were developed based on preliminary assumptions for the BRT design established during the MIS project. The New Bern Avenue BRT cost per mile was used for both phases because the New Bern Avenue BRT corridor conditions are most similar to the BRT conditions in Downtown in that minimal road-widening and minimal right-of-way acquisition are assumed. For this planning-level estimate the BRT vehicle costs and station costs were removed from the New Bern Avenue BRT cost per mile total and the assumed actual number of stations was added before applying the costs to each phase within Downtown. The vehicle costs were removed from the New Bern Avenue BRT cost per mile because it is assumed that additional BRT vehicles would not be needed for the addition of the Downtown BRT segments. These assumptions will need to be verified once the Downtown portion of each project is combined with the remaining portion outside of Downtown. Therefore, the initial New Bern Avenue BRT cost of $16.2M per mile was reduced to $13M per mile for the Downtown segments of the BRT. These costs will need to be further refined throughout project development of each BRT project.

TABLE 1 — ESTIMATED COST PER PHASE OF BRT IN DOWNTOWN RALEIGH

Implementation Phase	Miles	Estimated BRT Cost Per Mile	Estimated Cost Per Phase
Near-Term BRT (2023)	1.2 miles	$13,000,000	$15,600,000
Mid-Term BRT (2025)	2.4 miles	$13,000,000	$31,300,000

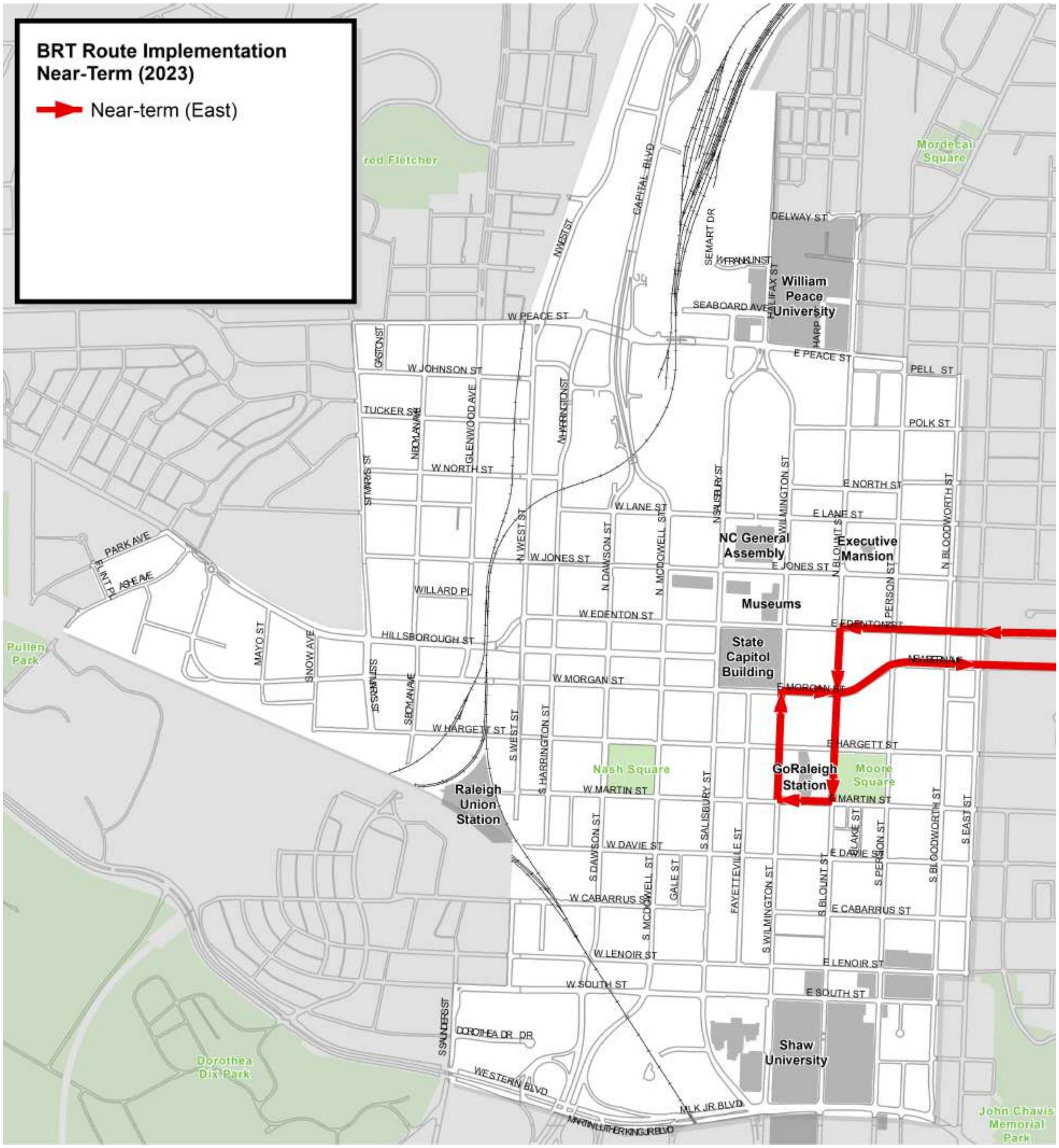
2.1 Near-Term BRT Network (2023)

The City of Raleigh announced in early 2019 that it would advance the eastern BRT corridor (New Bern Avenue) into FTA's Project Development first and proposed a schedule for this corridor which includes revenue service by 2023. The Downtown segment of the New Bern Avenue corridor is the proposed near-term BRT network in this plan. The near-term BRT network is shown on Figure 1, and includes BRT on Edenton Street, Morgan Street/New Bern Avenue, Wilmington Street, Blount Street and Martin Street. It is assumed that a BRT station would be located within or directly adjacent to the GoRaleigh Station, where currently over 6,000 transit riders pass through every day. Further study in the next phases of the project will be needed to determine if additional stations are needed within the Downtown study area limits.

The total on-street parking and loading zone impacts for the near-term BRT network are approximately 75 on-street parking spaces and 400 linear feet of loading zone space. Currently there are approximately 178 total on-street parking spaces and 727 linear feet of loading zone space along these streets so that results in a 42% reduction of on-street parking spaces and a 55% reduction in loading zone space. Additionally, there are a total of approximately 4,000 on-street parking spaces within the study area, so the near-term BRT would result in a 2% reduction in on-street parking for all of Downtown.

Lastly, there are approximately 24,000 total parking spaces Downtown, including on-street, surface parking, and parking decks, so the near-term BRT would result in 0.3% reduction in overall parking within Downtown.

FIGURE 1 — NEAR TERM BRT ROUTE IMPLEMENTATION



2.1.1 Blount and Person Street Two-Way Conversion

The City of Raleigh adopted the Blount Street/Person Street Corridor Plan in 2013 and implementation of the Plan is proposed over two phases. Phase I of the project includes resurfacing of portions of Blount Street, Person Street and Wake Forest Road as well as a road diet conversion for Wake Forest Road from four lanes to three lanes, including a center turn lane and bike lanes, from Person Street to Brookside Drive. Phase I also includes a road diet conversion of Blount and Person Streets from two or three lanes to two lanes with one-way bike lanes in each street from Wake Forest Road to Hoke Street. Construction for Phase I of the project is expected to be completed from July to December 2019.

Phase II of the project proposes analysis of the restoration of two-way traffic to Blount and Person Streets per the Corridor Plan. Should a two-way restoration be desired and prove feasible, Phase II would add roundabouts at the transitions with Wake Forest Road and Hammond Road and add new traffic signals at all signalized intersections on Blount and Person Streets. Two potential roundabouts would be added north and south of Capital Boulevard at Wake Forest Road as a part of the long-term plan for Capital Boulevard. Consideration and analysis will need to be done for how the two-way conversion will be impacted by the proposed BRT corridor on Blount Street between Edenton Street and MLK Jr. Boulevard. It may be beneficial for Blount Street to remain one-way where BRT is proposed due to concerns regarding BRT vehicle turning movements, efficient signal timing, less impacts to on-street parking/loading zones, etc. however more analysis is needed. See Section 3.5 of this report for more information on one-way versus two-way configurations. Design for Phase II is expected to begin in 2019.

Phase III is proposed to include streetscaping and street lighting of the Blount and Person Street corridors.

FIGURE 2 — BLOUNT STREET-PERSON STREET PHASE I IMPLEMENTATION RENDERING

Image Source: City of Raleigh

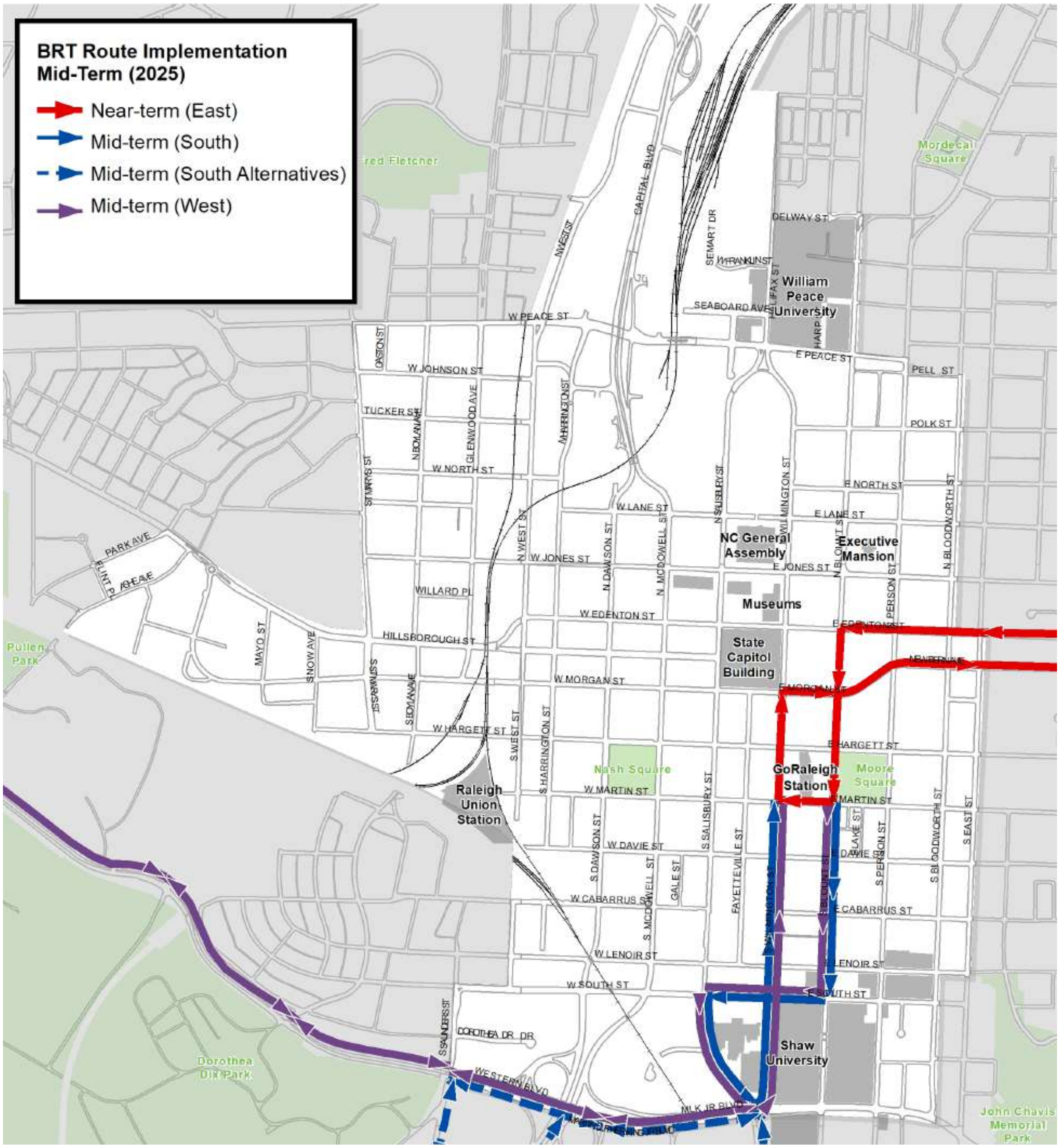
2.2 Mid-Term BRT Network (2025)

The mid-term BRT network assumes that the southern and western BRT corridors would be advanced next and that revenue service for these corridors is estimated by 2025. The mid-term BRT network is shown on Exhibit 3, and includes BRT on Martin Luther King Jr. Boulevard, Salisbury Street, South Street, Wilmington Street and Blount Street. This assumes that both the southern and western corridors would utilize the same BRT corridor within Downtown.

The intersection of Martin Luther King Jr. Boulevard at Wilmington/Salisbury Street operates with poor levels of service, long delays, and substantial queues today during the peak hours. In evaluating potential BRT routes through this intersection, it was initially suggested to route southbound BRT exiting Downtown along Blount Street. However, this created a potential left-turn movement for the BRT to travel from westbound Martin Luther King Jr. Boulevard to southbound Wilmington Street (if Wilmington Street becomes the selected corridor for BRT). Based on an initial evaluation of the geometry at this intersection, it is likely that allowing a median-running westbound left turn for the BRT would require an exclusive signal phase for the BRT. Given that adding additional signal phases at this location could worsen the operational issues during the peak hours, it was determined that the southbound BRT route exiting Downtown should instead be routed along South Street and Salisbury Street. Configuring the BRT routes in this manner would allow for more optimal signal phasing at the intersection of Martin Luther King Jr. Boulevard at Wilmington/Salisbury Street, which would lessen the operational impacts of the BRT implementation. This will need to be looked at in more detail during the next phase of the BRT projects once the southern BRT corridor is selected.

The total on-street parking and loading zone impacts for the near-term BRT network are approximately 66 on-street parking spaces and 170 linear feet of loading zone space. Currently there are approximately 107 total on-street parking spaces and 600 linear feet of loading zone space along these streets so that results in a 62% reduction of on-street parking spaces and a 28% reduction in loading zone space. Additionally, there are a total of approximately 4,000 on-street parking spaces within the study area, so the near-term BRT would result in a 2% reduction in on-street parking for all of Downtown. Lastly, there are approximately 24,000 total parking spaces Downtown, including on-street, surface parking, and parking decks, so the mid-term BRT would result in 0.3% reduction in overall parking within Downtown.

FIGURE 3 — MID-TERM BRT ROUTE IMPLEMENTATION

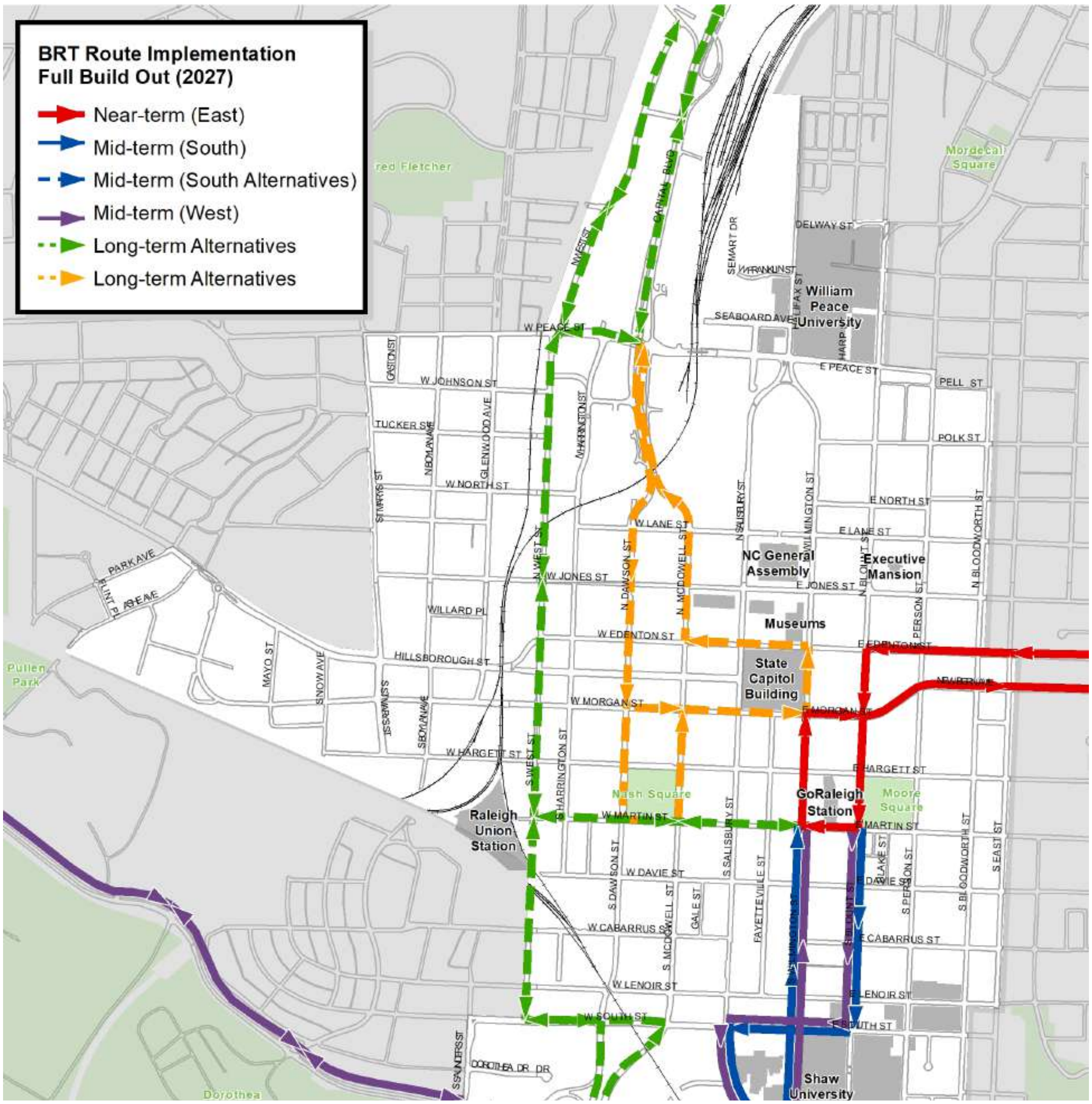


2.3 Full Build-out BRT Network (2027)

In the full build-out recommendation the near-term and mid-term BRT routes are shown along with a number of alternative routes, of which the final proposed routing will need to be determined based on certain key decisions and determinations in the upcoming years. The full-buildout BRT network is shown in Figure 4 below.

With variables such as upcoming proposed mixed-use developments, future commuter rail, a future bus station at Raleigh Union Station (RUSBus), and the proposed West Street extension project, these alternate BRT corridors provide flexibility while still offering guidance for further study as these variable elements play out in the upcoming years. For more information see Section 7.0.

FIGURE 4 — FULL BUILD OUT BRT ROUTE IMPLEMENTATION



2.3.1 Martin Street and Hargett Street Alternative

The Martin Street long-term BRT alternative as indicated in Figure 4 proposes two-way BRT operation on Martin Street and one general-purpose traffic lane traveling eastbound, see Figure 5 for conceptual layout. Throughout the scenario development process this was proposed as one alternative to provide BRT access from the east side of Downtown to the west side as well as between Raleigh Union Station and GoRaleigh Station. Another alternative proposed and considered was operating the BRT one-way on Hargett Street and in the opposite direction on Martin Street creating a one-way BRT pair (see Figure 6). This alternative would allow two-way operation for general-purpose traffic on both streets to remain and would only require removal of on-street parking and loading zones on one side of each street to accommodate the BRT lanes. Another advantage to this alternative would be the ability to time traffic signals to progress BRT movements in both directions across Downtown (between GoRaleigh Station and the future Raleigh Union Station bus facility) in a highly-efficient manner, improving BRT speed and reliability.

Two-way BRT operation on Martin Street was ultimately selected by members of the Project's Technical Team due to idea that this would minimize impacts to only one street rather than two, which may be more favorable to the public and to Downtown business owners along these streets. However, because the BRT final alignments have not been determined at the time of this study, it is recommended that both two-way BRT on Martin Street and a one-way BRT pair on Martin and Hargett Streets should be further analyzed in the next phases of the BRT projects.

It should also be noted that the Raleigh Civic Campus Master Plan completed in 2018 calls for Hargett Street to be a "pedestrian priority street" between the civic campus and Nash Square. This would involve street materials and other features promoting very slow traffic in this block, and potentially set the street up for frequent closures for various events. This treatment could potentially impact the viability of Hargett Street to serve as a BRT street in either direction. This would particularly be the case if the street would be subject to regular closures for festivals and other events. If the Martin and Hargett Street one-way BRT pair alternative is ultimately selected, then the design and functionality of Hargett Street in conjunction with the Civic Campus development must consider this issue and minimize impacts to BRT operation in this block.

FIGURE 5 — TWO-WAY BRT OPERATION ON MARTIN STREET CONCEPTUAL LAYOUT

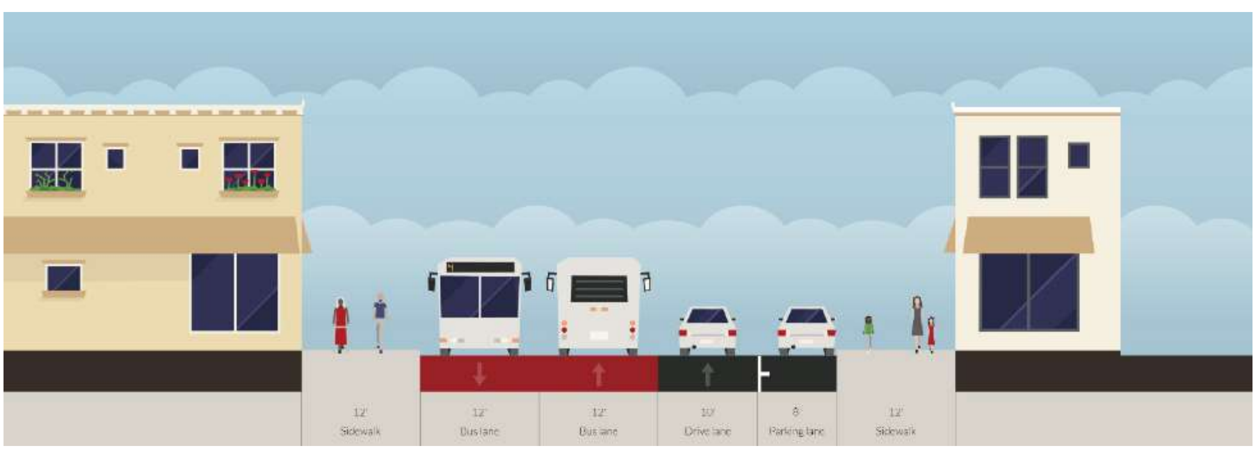
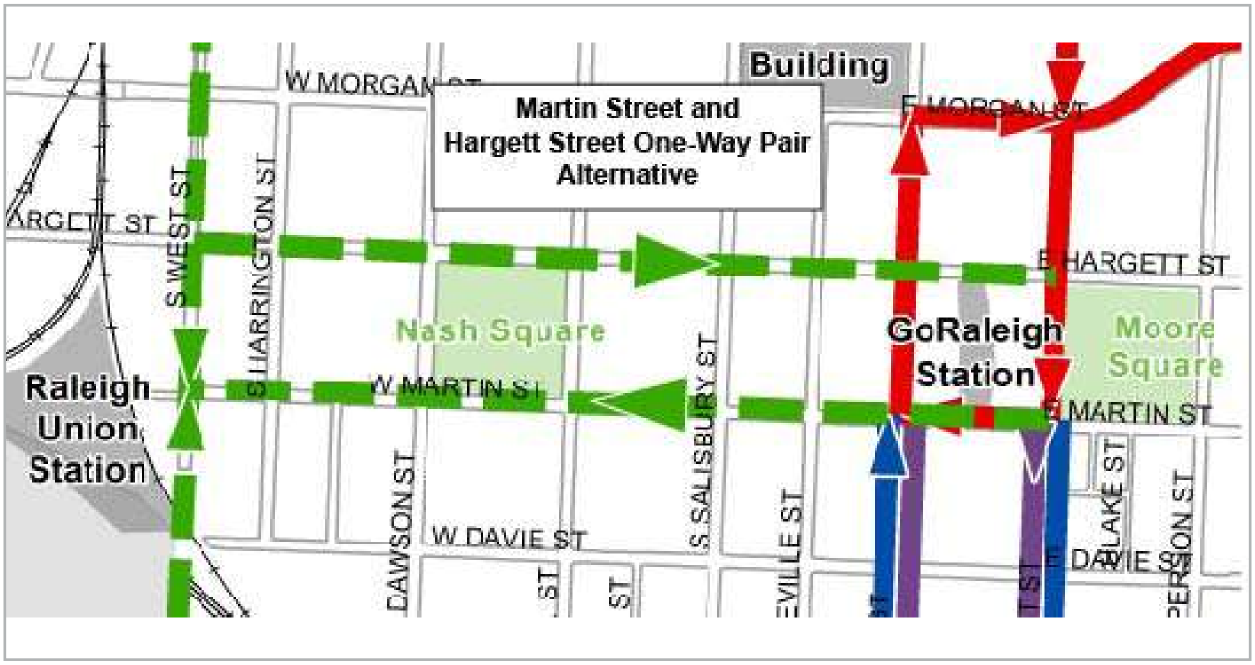


FIGURE 6 — MAP OF BRT ONE-WAY PAIR ON MARTIN AND HARGETT STREETS ALTERNATIVE



3.0 Transit Operations Analysis

3.1 Bus Lane Capacity

One key assumption with the addition of BRT lanes in Downtown Raleigh is the number of vehicles (both BRT and local bus) that can be accommodated in the proposed dedicated bus lanes on Downtown streets. TCRP Report 165 Transit Capacity and Quality of Service Manual (TCRP 165) presents information to estimate how many vehicles per hour can be accommodated in exclusive bus lanes. Specific inputs required to determine bus lane capacity include:

- bus stop locations
- geometry of the bus stop
- the number of bays provided at each stop
- the cycle time for adjacent traffic signals
- the number of vehicles/hour for adjacent traffic lanes
- the number of right turning vehicles (if right turns are permitted from the bus lane)
- the pedestrian volumes at adjacent intersections
- the assumed dwell time of each stopping
- an assumed coefficient of dwell variation
- the design bus stop failure rate (the rate at which a bus will arrive to find all bays occupied by other vehicles)

This detailed information has not been determined yet and will be developed as part of preliminary engineering and final design for each of the BRT projects. However, TCRP 165 also includes information for planning purposes on bus lane capacity, shown in Table 2, which recommends an estimated average of 30 buses per hour can be accommodated in each Downtown exclusive bus lane and still maintain stable and unconstrained flow. This would equate to a vehicle (BRT or local bus) every 2 minutes.

TABLE 2 — BUS LANE CAPACITY TABLE FROM TCRP REPORT 165

Description	Service Volume bus/lane/h	Average bus/lane/h
ARTERIAL STREETS		
Free flow	25 or less	15
Stable flow, unconstrained	26 to 45	35
Stable flow, interference	46 to 75	60
Stable flow, some platooning	76 to 105	90
Unstable flow, queuing	106 to 135	120
Forced flow, poor operation	over 135*	150*
DOWNTOWN STREETS		
Free flow	20 or less	15
Stable flow, unconstrained	21 to 40	30
Stable flow, interference	41 to 60	50
Stable flow, some platooning	61 to 80	70
Unstable flow, queuing	81 to 100	90
Forced flow, poor operation	over 100*	110*

Sources: Hoey and Levinson (*12*) and *Transportation Research Circular 212* (*13*).

Notes: *Results in more than one-lane operation. The values for forced flow conditions should not be used for planning or design. They are merely given for comparative purposes.

Bus volumes shown assume all buses make regular stops along the street.

3.2 BRT Lanes Shared With Bus Routes

This section describes the coordination of BRT service with other GoRaleigh and GoTriangle routes in Downtown Raleigh. The recently completed Wake Bus Plan (10-year Bus Operating and Capital Plan) will greatly expand local and regional bus services operating in the Downtown area. The Wake Bus Plan also proposes a High Frequency Network (HFN) of bus routes which would operate every 15-minutes. This section assesses each of the proposed BRT implementation phases and makes recommendations on how the proposed expanded bus network might adjust with the addition of BRT service.

The first step in this analysis was to determine if the proposed exclusive BRT lanes could accommodate additional trips from the HFN, based on the assumption of 30 buses per lane per hour discussed in section 3.1. With this kind of frequency, it would be necessary for services sharing exclusive BRT lanes to adjust their schedules to evenly distribute trips through Downtown. Lower frequency bus routes (20-minute frequency or less) are not recommended to share Downtown exclusive lanes with BRT because the timing and coordination would be very difficult to achieve.

Instead, this analysis assumes the high frequency network routes (15-minute frequency or greater) could share the exclusive lanes with BRT in Downtown Raleigh. It is assumed that these routes will have the highest ridership in the system, so more riders would benefit from the travel time savings and reliability associated with dedicated bus lanes. Further, higher frequencies mean these routes are less reliant on coordinated transfers and can therefore adjust schedules to smooth operations in each shared exclusive bus lane.

BRT lines in Downtown Raleigh are proposed to operate with 10-minute frequency, resulting in 6 BRT vehicles per hour, per lane. It is possible that two BRT services would utilize the same alignment, resulting in a total of 12 BRT vehicles per hour, per lane in those segments. However, this would only occur in the 2027 full implementation period.

Using the 30 trips per hour, per lane assumption: exclusive lanes could accommodate an additional 18 trips per hour (if two BRT services are in operation) or up to 24 trips per hour (if only one BRT service is in operation). Based on these numbers, between 4 and 6 high frequency routes could potentially also operate in the exclusive lanes with BRT, depending on where these routes enter the exclusive lanes and how far they travel in them. Therefore, the next step in the analysis is to determine on where each high frequency route travels within Downtown and where exclusive lanes are proposed for BRT in each phase of implementation.

According to the recently completed Wake Bus Plan, a total of seven routes that enter Downtown are proposed to have 15-minute weekday, daytime frequency:

- 3 Glascock
- 5 Biltmore Hills
- 6 Glenwood
- 8 Six Forks Midtown
- 9 Hillsborough
- 11 Avent Ferry
- 19 MLK/Sunnybrook

Three of these routes (3, 5, 19) originate on the east side of Raleigh and are planned to terminate at Raleigh Union Station on west side of Downtown. Four other routes (6, 8, 9, 11) originate on the north or west sides of Raleigh and are planned to terminate at GoRaleigh Station. Figure 7 shows the proposed 2027 High Frequency Bus Network from the Wake Bus Plan.

The Wake Bus Plan also goes on to recommend when these routes would be upgraded to high frequency status:

- 2023 and before: route 19 (FY19) and route 9 (FY21)
- 2024-25: routes 5, 6, and 8 (FY24)
- 2026-27: routes 3 and 11 (FY26)

Based on these implementation dates and the proposed BRT implementation plan, the high frequency network was reviewed in two ways:

1. To ensure the BRT lanes are not over capacity with the operation of both BRT and the proposed High Frequency Network according to the Wake Bus Plan.
2. Determine if any of the High Frequency Network routes could be relocated to share the proposed BRT lanes.

Table 3 shows the trips per hour by segment for BRT and high frequency network in Downtown Raleigh for the capacity analysis. For Near (2023) and Mid-term implementation (2025), none of the proposed dedicated lanes would reach full capacity. One potential issue in the Full Implementation (2027) network could be on Martin Street if the high frequency network and multiple BRT lines were to use this segment. Once decisions are made on the full build network, another review of the high frequency network should take place to understand the impacts.

The next review of the High Frequency Network was to determine if any routes could be moved to share the proposed dedicated BRT lanes. For example, in the mid-term plan exclusive BRT lanes are proposed on Blount and Wilmington streets. Two high frequency bus routes, Route #5 and Route #19, could shift their alignment to Wilmington Street for inbound trips take advantage of the dedicated BRT lane. Table 4 shows the proposed alignment changes to high frequency routes in each implementation year. Note that much of the 2027 full build is to be determined. The proposed Downtown BRT and high frequency network for each implementation year are shown graphically in Figures 8-10.

FIGURE 7 — 2027 WAKE BUS PLAN HIGH FREQUENCY BUS NETWORK IN DOWNTOWN

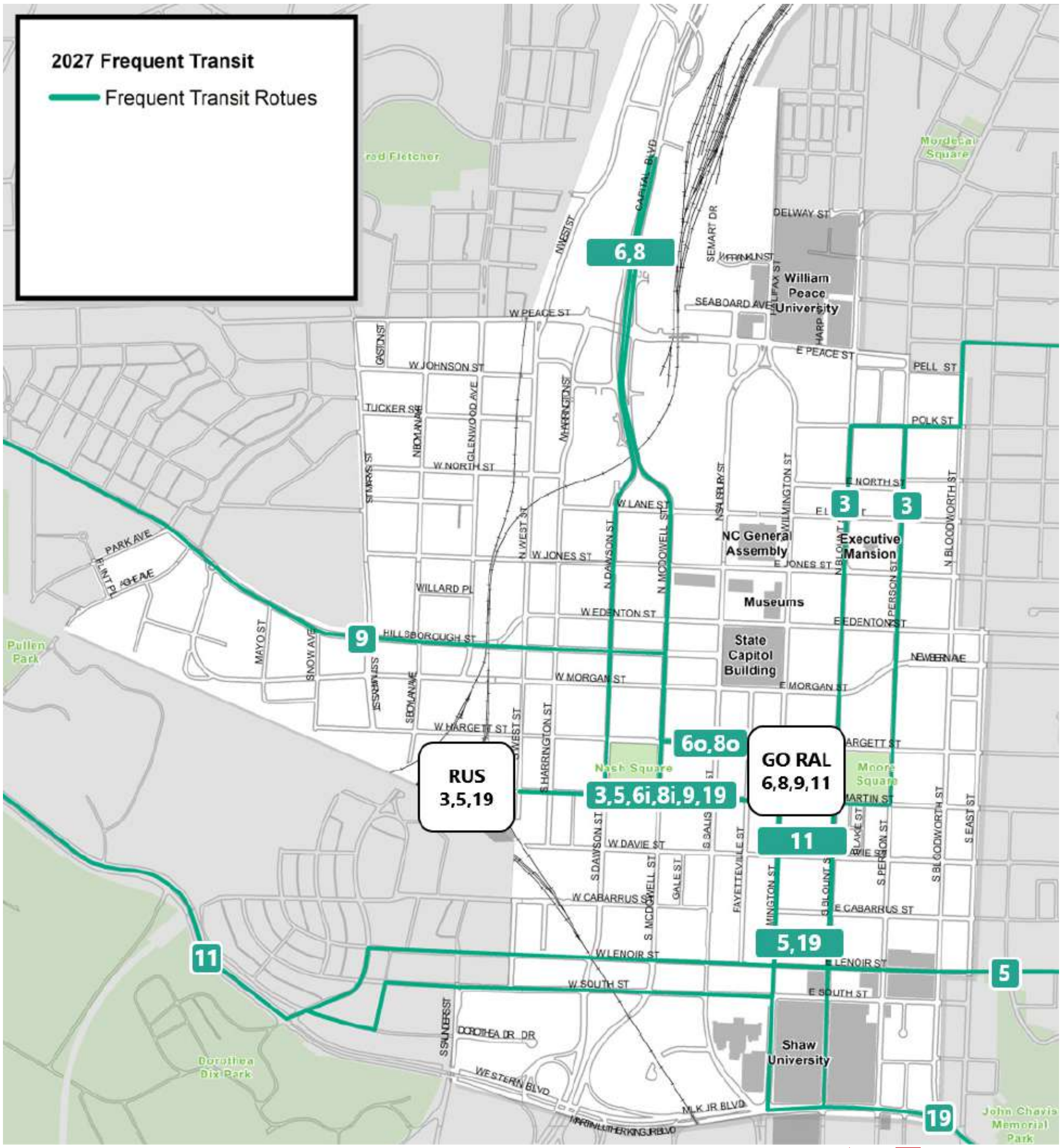


TABLE 3 — TRIPS PER HOUR BY STREET SEGMENT AND IMPLEMENTATION YEAR

	2023 HFN Only	2023 HFN+BRT	2025 HFN+BRT	2027 HFN+BRT
North/South streets north of Martin Street				
West Street				TBD
Dawson Street	4	4	12	TBD
McDowell Street	4	4	12	TBD
Wilmington Street		6	6	6
Blount Street		6	6	10
Person Street				4
North/South streets south of Martin Street				
West Street				TBD
Dawson Street				TBD
McDowell Street				TBD
Wilmington Street			20	24
Blount Street	4	4	20	24
Person Street	4	4		
East/west streets				
Peace Street				
Hillsborough Street	4		4	4
Edenton Street				TBD
Morgan Street				TBD
Hargett Street				TBD
Martin Street	8		20	TBD
South Street				4
Lenoir Street				4

Note: Table shows the maximum trips per hour for the segment. In some cases the trips per hour changes when a route turns on or off the segment.

TABLE 4 — PROPOSED ALIGNMENT CHANGES FOR EACH LOCAL ROUTE BY IMPLEMENTATION YEAR

Route	From Wake Bus Plan		2023	2025	2027
	Inbound	Outbound	Proposed Changes	Proposed Changes	Proposed Changes
3	Polk St. Blount St.	Person St. Polk St.	-	-	no change
5	Lenoir St. Person St.	Blount St. Lenoir St.	-	Shift inbound from Person St. to Wilmington St.	same as 2025
6	Capital Blvd. Dawson St. Martin St.	Hargett St. McDowell St. Capital Blvd.	-	no change	to be determined by proposed BRT alignment
8	Capital Blvd. Dawson St. Martin St.	Hargett St. McDowell St. Capital Blvd.	-	no change	to be determined by proposed BRT alignment
9	Hillsborough St. Dawson St. Hargett St.	Martin St. McDowell St. Hillsborough St.	no change	no change	to be determined by proposed BRT alignment
11	Lenoir St. Wilmington St.	Blount St. South St.	-	-	no change
19	MLK Jr. Blvd. Person St.	Blount St. MLK Jr. Blvd.	no change	Shift inbound from Person St. to Wilmington St.	same as 2025

FIGURE 8 — 2023 BRT AND HIGH FREQUENCY BUS NETWORK IN DOWNTOWN RALEIGH

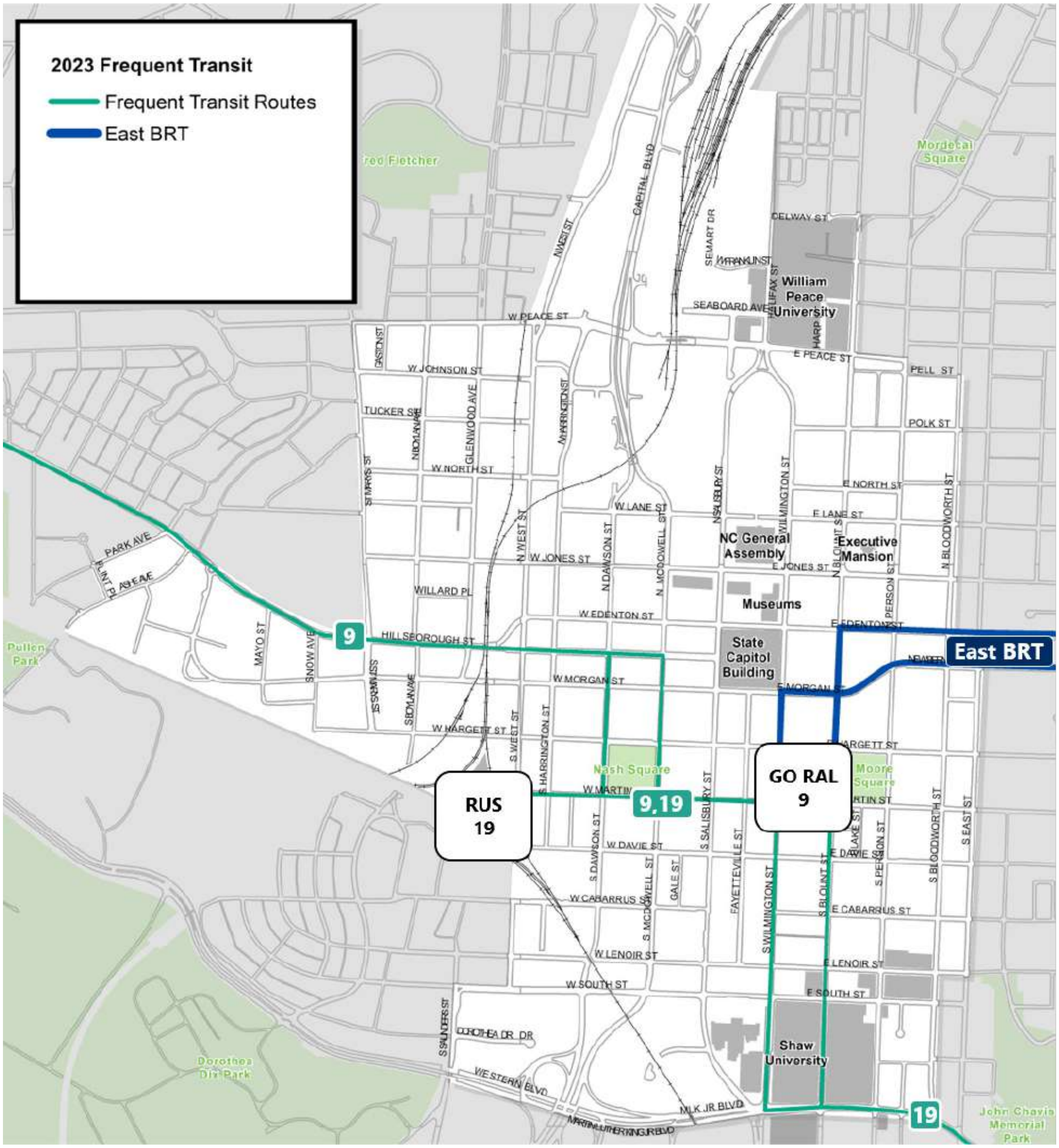


FIGURE 9 — 2025 BRT AND HIGH FREQUENCY BUS NETWORK IN DOWNTOWN RALEIGH

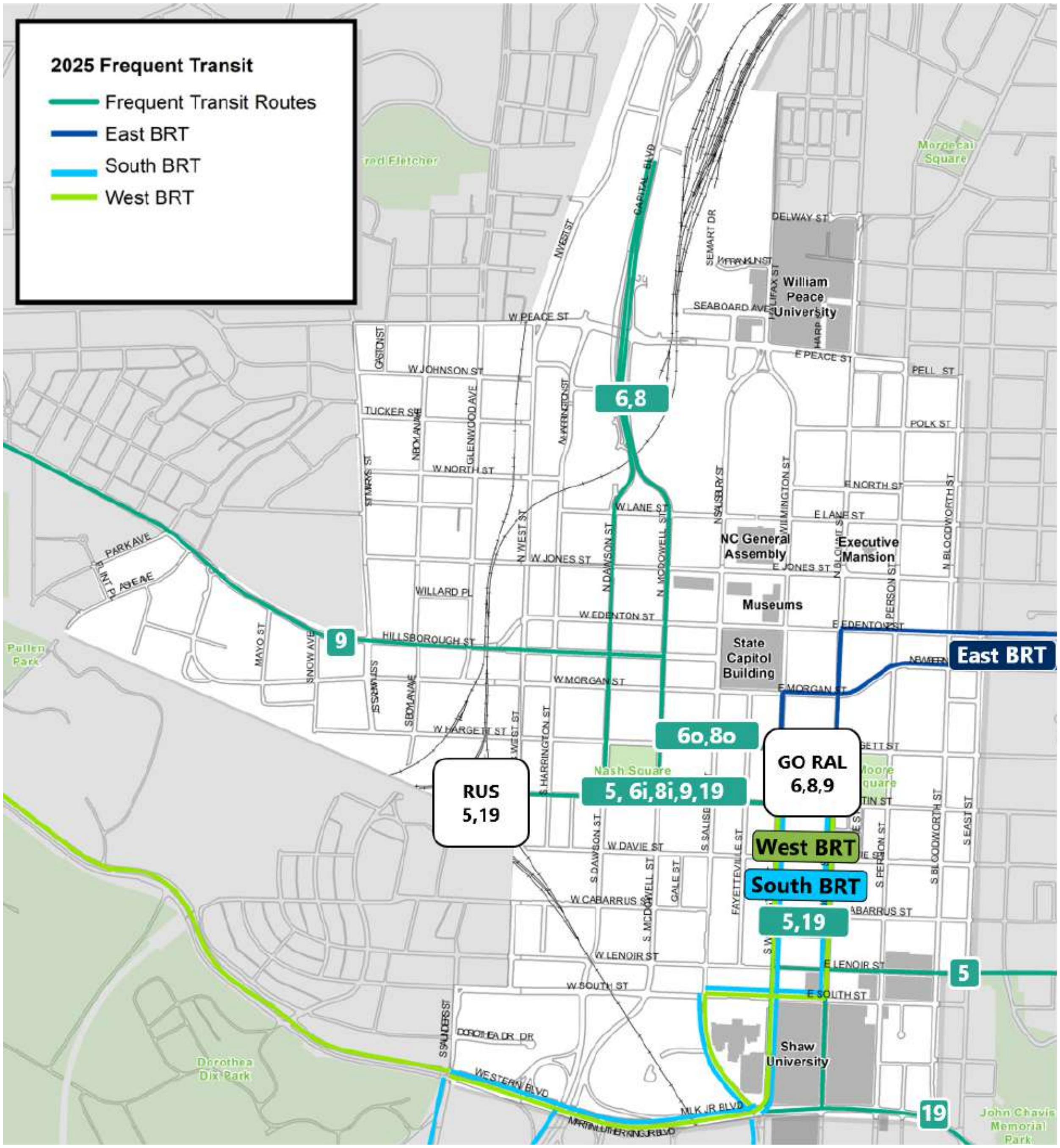
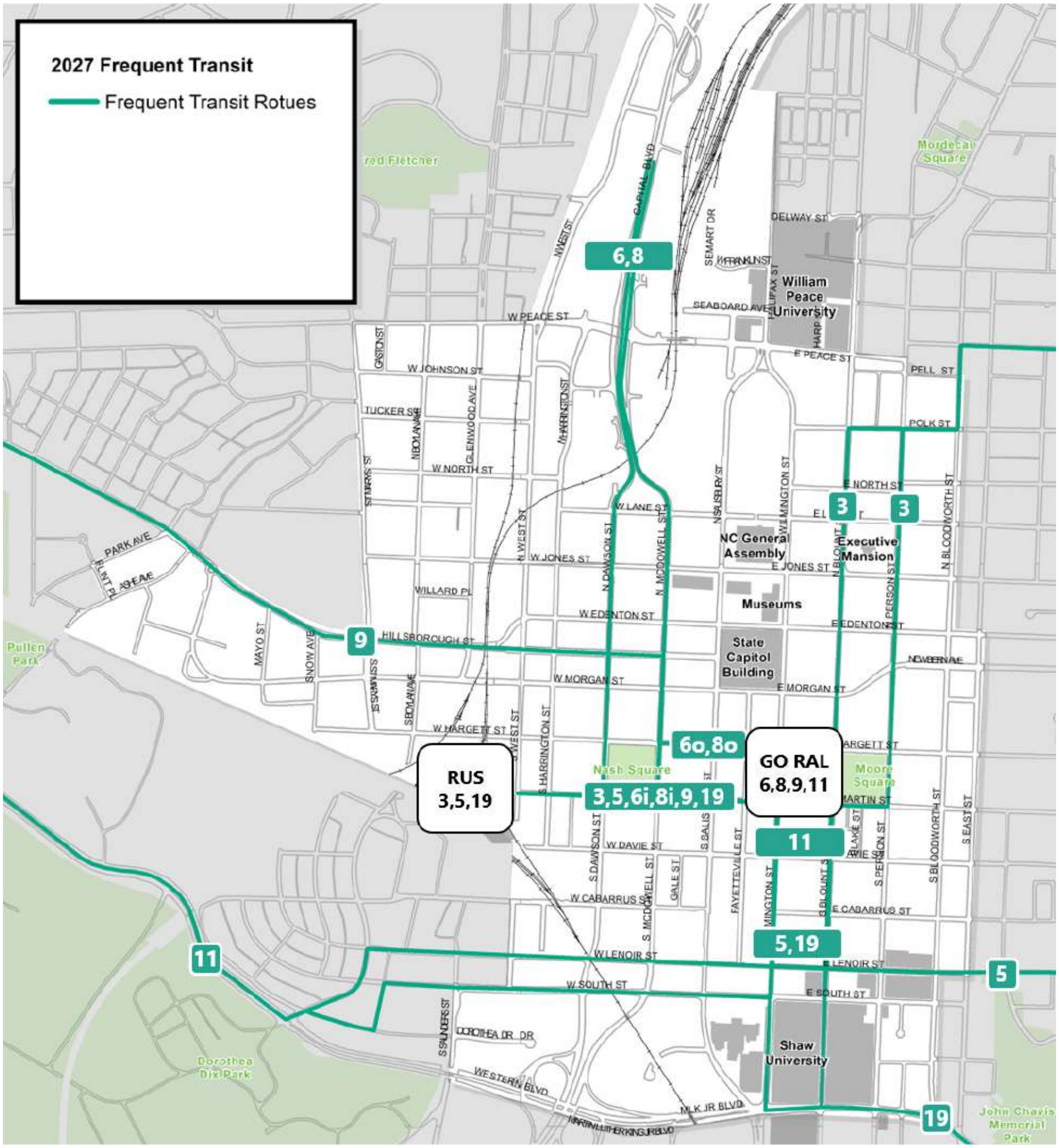


FIGURE 10 — 2027 BRT AND HIGH FREQUENCY BUS NETWORK IN DOWNTOWN RALEIGH



3.3 BRT Travel Time Analysis: Benefit of Dedicated Lane

This section focuses on the travel time benefits of a dedicated transit lane for BRT operations in Downtown Raleigh. There are two main benefits for constructing a dedicated lane:

1. Average travel time improvement: On average, a BRT vehicle will be able to travel through Downtown Raleigh faster with a dedicated lane than in mixed traffic
2. Reliability: BRT with a dedicated lane will typically have more consistent travel times than operating in mixed traffic

3.3.1 Average Travel Time Analysis

Calculating the travel time improvement requires revisiting the travel time estimates first discussed in Section 4.5 of Volume 2: Scenario Evaluation Report. There are three main components of BRT travel time:

1. Time in-motion
2. Intersection delay
3. Dwell time at stations

A dedicated lane reduces the amount of in-motion delay because the BRT vehicle will not encounter automobiles as it makes its trip. Conversely, a BRT vehicle operating in mixed traffic will encounter more delay. This is expressed in the travel time model as "level of service (LOS)." A BRT vehicle operating in a dedicated lane has a segment or intersection LOS of "A," which is a proxy for saying there are no delays between intersections while operating in the dedicated lane. A BRT vehicle operating in mixed traffic is assigned the prevailing LOS, which translates to the delay that comes from operating in mixed traffic conditions.

Using this process, the travel time model was run twice: once assuming a dedicated BRT lane and again assuming BRT operating in mixed traffic. The traffic model used for this analysis includes only existing traffic volumes provided from with City. The results are shown in Table 5. The dedicated lane consistently provides a travel time savings compared to operations in mixed traffic. The amount of savings depends on the traffic conditions and the length of the corridor. For example, operations on Martin and West streets show a 1.4-minute savings between dedicated lane and mixed traffic operations. These streets will see more mixed traffic BRT delay due to intersection conditions (due to the lack of signal progression), along with the increase in delays that come from a narrow street not equipped to handle the intensity of new development. By comparison, a much shorter segment between GoRaleigh Station and East Street only shows a 0.1-minute difference, which is mainly due to the short length of the lanes assessed and also because better traffic conditions in this part of Downtown Raleigh result in a very small difference between mixed traffic and dedicated lane operations.

The expectation may be for a larger difference between mixed traffic and dedicated lanes, but there are two good reasons for the results we see here. One reason is because of the short distance for these alignments in Downtown Raleigh. Analyzing short portions of longer alignments will show a smaller difference between mixed traffic and dedicated lanes than analyzing the entire length of each BRT route. To put it another way, a 0.2-minute difference over 0.5 miles in Downtown Raleigh would result in a 4.0-minute savings in a 10-mile-long BRT corridor. Furthermore, 4 minutes of travel time savings per trip can equate to hours when applied over time and over the number of transit riders that benefit from this saving. The other reason is because most streets in Downtown already benefit from efficient signal progression (meaning the delay times at intersections are already very short). Therefore, the dedicated BRT lanes on these corridors do not provide much advantage (especially for very efficient corridors such as Dawson and McDowell Streets). While this is true currently, if traffic volumes increase and/or additional congestion occurs in Downtown in the future, the advantages of dedicated BRT lanes would be expected to increase substantially.

Table 5 lists various street segments, along with estimated travel times for BRT in dedicated transit lanes as well as in mixed traffic and the difference between those travel times. An effectiveness rating is also shown indicating how effective the dedicated lane is in reducing travel time along that street segment in comparison to the other street segments where BRT is proposed. The street segments with the highest effectiveness ratings are West Street and Martin Street. The 1.4-minute difference results largely from these streets not currently benefitting from signal progression in Downtown Raleigh. As a result, the dedicated lane provides a larger advantage on these streets compared to the others in Downtown.

TABLE 5 — AVERAGE EXPECTED TRAVEL TIME: MIXED AND DEDICATED LANE COMPARISON

Year	2023		2025		2027			
Streets	Edenton, Blount	Wilmington, New Bern	Blount, South, Salisbury, MLK	MLK, Wilmington	Capital, Dawson, Martin	Martin, McDowell, Capital	West, Martin	Martin, West
Direction	Westbound	Eastbound	Southbound	Northbound	Southbound	Northbound	Southbound	Northbound
From	East St	GoRaleigh Station	GoRaleigh Station	Dawson/ McDowell	Peace St	GoRaleigh Station	Peace St	GoRaleigh Station
To	GoRaleigh Station	East St	Dawson/ McDowell	Peace St	GoRaleigh Station	Peace St	GoRaleigh Station	Peace St
Mixed Traffic	4.4 min	4.4 min	9.5 min	4.6 min	7.1 min	5.8 min	11.5 min	11.2 min
Dedicated Lane	4.3 min	4.4 min	9.2 min	4.2 min	6.7 min	5.4 min	10.2 min	9.8 min
Travel Time Difference	-0.1 min	-0.1 min	-0.3 min	-0.4 min	-0.4 min	-0.3 min	-1.4 min	-1.4 min
Travel Time Improvement	3%	2%	3%	8%	6%	5%	12%	12%
Effectiveness Rating	Low	Low	Low	Medium	Medium	Medium	High	High

3.3.2 Travel Time Reliability

Consistency of operations that comes with a dedicated lane is a critical factor in this assessment because a consistent travel time is one meaningful way to attract riders to use the BRT network. To assess reliability, variability curves were developed and applied to the travel time model. Three variability curves were developed:

- lane operations
- dwell times
- traffic signal delay

Each curve was based on observation of existing BRT services, primarily using a publicly available Application Programming Interface (API) feed and shows how likely a certain amount of delay would occur during BRT operations. While three curves are available, only two variability curves were applied for Downtown Raleigh, one for lane operations and one for dwell time. The study team decided to not include variability for intersection delay because of the unique nature of the signal progression on Downtown Raleigh streets, which provides some travel time consistency already.

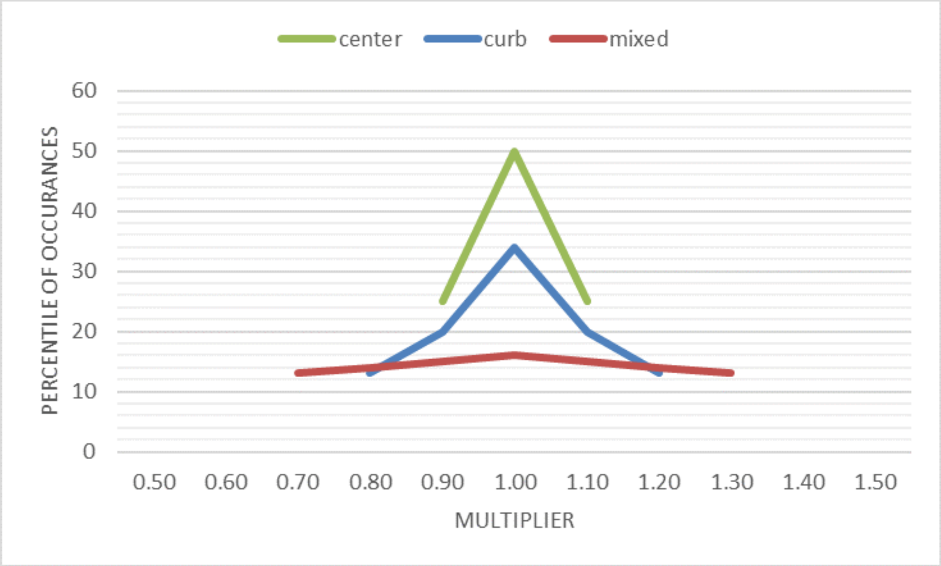
The variability curves are expressed as a multiplier of the expected travel time developed in the travel time model. For example, the average expected dwell time delay at Raleigh Union Station is 35 seconds in the travel time model. The variability curve shows the percent chance of that dwell time occurring. A multiplier of 0.6 is expected to occur 45 percent of the time. This means that when the variability is applied to the model, the following equation is used to calculate the dwell time for 45% of the trips:

Delay for 45% of trips = 35 seconds x 0.6 = 21 seconds

When variability is applied over a large number of trips, the average comes out to the expected 35 seconds provided in the static travel time model.

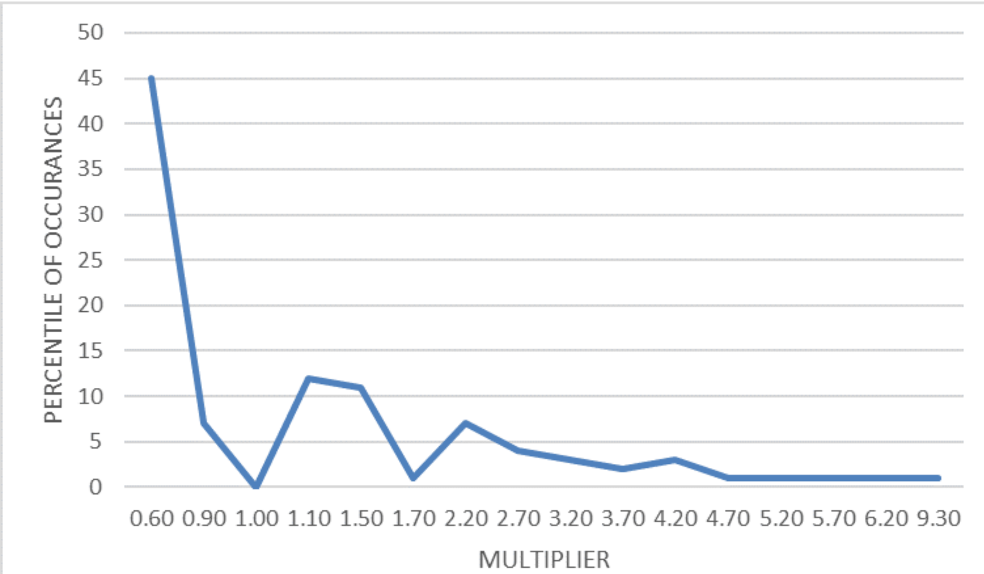
The two variability curves applied to the model are shown in Figure 11 and Figure 12.

FIGURE 11 — LANE OPERATIONS VARIABILITY MULTIPLIER



Source: Connectics Transportation Group observation of bus lane operations in Broward County, Florida, 2017.

FIGURE 12 — DWELL TIME VARIABILITY CURVE



Source: Transit arrival and departure data through publicly available API feed; data collected and processed for two BRT lines (A Line in St. Paul, MN and Orange Line in Los Angeles) in October 2018.

The random numbers feature in Microsoft Excel was used to generate a location on the variability curve, which in turn determines the multiplier, and thus the expected lane operations or dwell time. When applied over multiple segments and stations in the model, the result is a range of outcomes that shows the lower and upper bounds of the potential BRT travel times through Downtown Raleigh.

Table 6 shows the result of applying the variability to each proposed BRT project, for both mixed traffic and dedicated lanes. As noted previously, BRT in dedicated lanes is expected to be more consistent compared to mixed traffic operations, especially in a Downtown setting. Accordingly, the range of travel times tends to be narrower for dedicated lane operations. For example, the range of travel times for westbound BRT on Edenton and Blount streets shows the mixed traffic range is 3.7 to 11.5 minutes, while the dedicated BRT range is 3.7 to 11.2 minutes. This smaller range for the dedicated lane is because it is more reliable.

It should be noted that the random numbers used to generate lookups on the variability curve results in some cases where the mixed traffic range outperforms the dedicated lane range from each model. This is to be expected and is a result of random chance. The majority of the outcomes; however, show dedicated lanes with the more consistent BRT performance over BRT operating in mixed traffic.

TABLE 6 — RELIABILITY ANALYSIS: MIXED AND DEDICATED LANE COMPARISON

Year	2023		2025		2027			
Streets	Edenton, Blount	Wilmington, New Bern	Blount, South, Salisbury, MLK	MLK, Wilmington	Capital, Dawson, Martin	Martin, McDowell, Capital	West, Martin	Martin, West
Direction	Westbound	Eastbound	Southbound	Northbound	Southbound	Northbound	Southbound	Northbound
From	East St	GoRaleigh Station	GoRaleigh Station	Dawson/ McDowell	Peace St	GoRaleigh Station	Peace St	GoRaleigh Station
To	GoRaleigh Station	East St	Dawson/ McDowell	Peace St	GoRaleigh Station	Peace St	GoRaleigh Station	Peace St
Mixed Traffic Range	3.7–11.5 min	3.8–11.3 min	8.7–16.6 min	3.7–11.7 min	6.2–14.1 min	4.9–13.7 min	10.5–21.4 min	9.9–19.8 min
Mixed Traffic 90th Percentile	7.8 min	7.5 min	7.9 min	8.0 min	7.9 min	8.8 min	10.9 min	9.9 min
Dedicated Lanes Range	3.7–11.2 min	3.8–11.4 min	8.4–13.6 min	3.6–11.1 min	6.0–12.6 min	4.7–12.9 min	9.3–16.2 min	0.0–18.2 min
Dedicated Lanes Range Magnitude	7.5 min	7.6 min	5.2 min	7.5 min	6.6 min	8.2 min	6.9 min	9.2 min
Reliability Improvement (Difference between dedicated and mixed traffic ranges)	0.3	-0.1	2.7	0.5	1.3	0.6	4	0.7
Effectiveness Rating	Low	Low	High	Medium	High	Medium	High	Medium

Volume Three

3.4 One-Way Versus Two-Way Street Analysis

One-way and two-way street configurations each have advantages and disadvantages with regard to BRT operations as well as other pedestrian and transit rider experience. This section discusses how each configuration could impact BRT operations and other factors in Downtown Raleigh.

3.4.1 One-Way Configuration

The main benefits of operating vehicles on a one-way street are mobility and speed. Because one-way streets only move in a single direction, it is much easier to design these streets to move a greater number of vehicles more efficiently. Traffic signals can be designed for more effective progression and there are no opposing movements to conflict with the prevailing direction. BRT service can also benefit from this by making the trip speed is faster, which contributes to a faster end-to-end trip time. Additionally, there could potentially be a small operational cost savings if the faster speeds can save a driver block during scheduling, however, further analysis would be needed as this depends on the end-to-end travel time of the BRT, which includes segments outside of Downtown Raleigh that are beyond of the limits this project. Another advantage that should be noted is that one-way street intersections have fewer directions from which turning vehicles are approaching and fewer turning movements. This reduces the number of conflicts and the amount of information that the pedestrian or cyclist has to process as they cross an intersection.

There are also a few disadvantages to BRT service on one-way streets. One is customer expectation. Riders who exit a BRT vehicle on a one-way street would need to find an adjacent street in the opposite direction for their return trip. For example, proposed BRT service on Wilmington and Blount Streets would enter Downtown northbound via Wilmington Street and exit southbound via Blount Street. A rider exiting on Wilmington Street would need to walk one block east to Blount Street for the return trip home. While riders will eventually learn the pattern (and cell phone technology and wayfinding can help), BRT operations on one-way streets have a higher barrier to entry for new riders and visitors using the system for the first time. Another concern associated with one-way streets is the speed of motor vehicles resulting from signal progression and the removal of conflict from opposing movements. This combination can promote higher speeds on one-way streets, which can negatively impact the comfort level for pedestrians and bicyclists. However, signal timing can be modified to set the progression of vehicles on one-way streets at a lower speed if desired.

3.4.2 Two-Way Configuration

Two-way streets tend to operate at a slower speed than one-way streets because drivers must account for travel in both directions, and signal progression is harder to incorporate as effectively, equating to more overall traffic delay. This can result in slower speeds and longer travel times which would negatively impact BRT operations. While slower speeds may be more comfortable to pedestrians and cyclists adjacent to the traffic, a balance must be achieved in order to ensure that BRT operates efficiently and reliably.

Slower speeds have negative impacts on BRT operations as well as other bus operations within Downtown. End-to-end travel times for BRT and other routes being longer could translate to a slightly higher operating cost if it requires an additional driver block during scheduling, however, further analysis would be needed as this depends on the end-to-end travel time of the BRT, which includes segments outside of Downtown Raleigh that are beyond of the limits this project. Slower speeds resulting in longer trip times result in a negative impact on transit riders as well as it requires more time to get to their destination.

Another issue with a two-way configuration is that the tighter radii at intersections in Downtown make it more difficult for a BRT vehicle (and all buses) to make turns (see Figures 13 and 14). This is typically a problem for right-turn movements onto two-way streets. Current bus operations are already impacted by this condition at certain intersections in Downtown Raleigh, and this problem would be exacerbated with further conversion to two-way streets Downtown. Current bus routes are focused heavily on the one-way streets Downtown due to the various advantages of one-way conditions for bus operations. Table 7 summarizes each configuration option.

The conversion to two-way may also result in overall lane width reductions which is undesirable for BRT operations since narrower lanes leads to decreased speed and increased likelihood of contact with other vehicles. Also, reduction in the number of through lanes adjacent to the bus lane may increase the likelihood of non-transit vehicles using the bus lanes to bypass traffic.

FIGURE 13 — GORALEIGH BUS RIGHT-TURN ON TWO-WAY STREET IN DOWNTOWN

FIGURE 14 — GORALEIGH BUS RIGHT-TURN ON TWO-WAY STREET IN DOWNTOWN

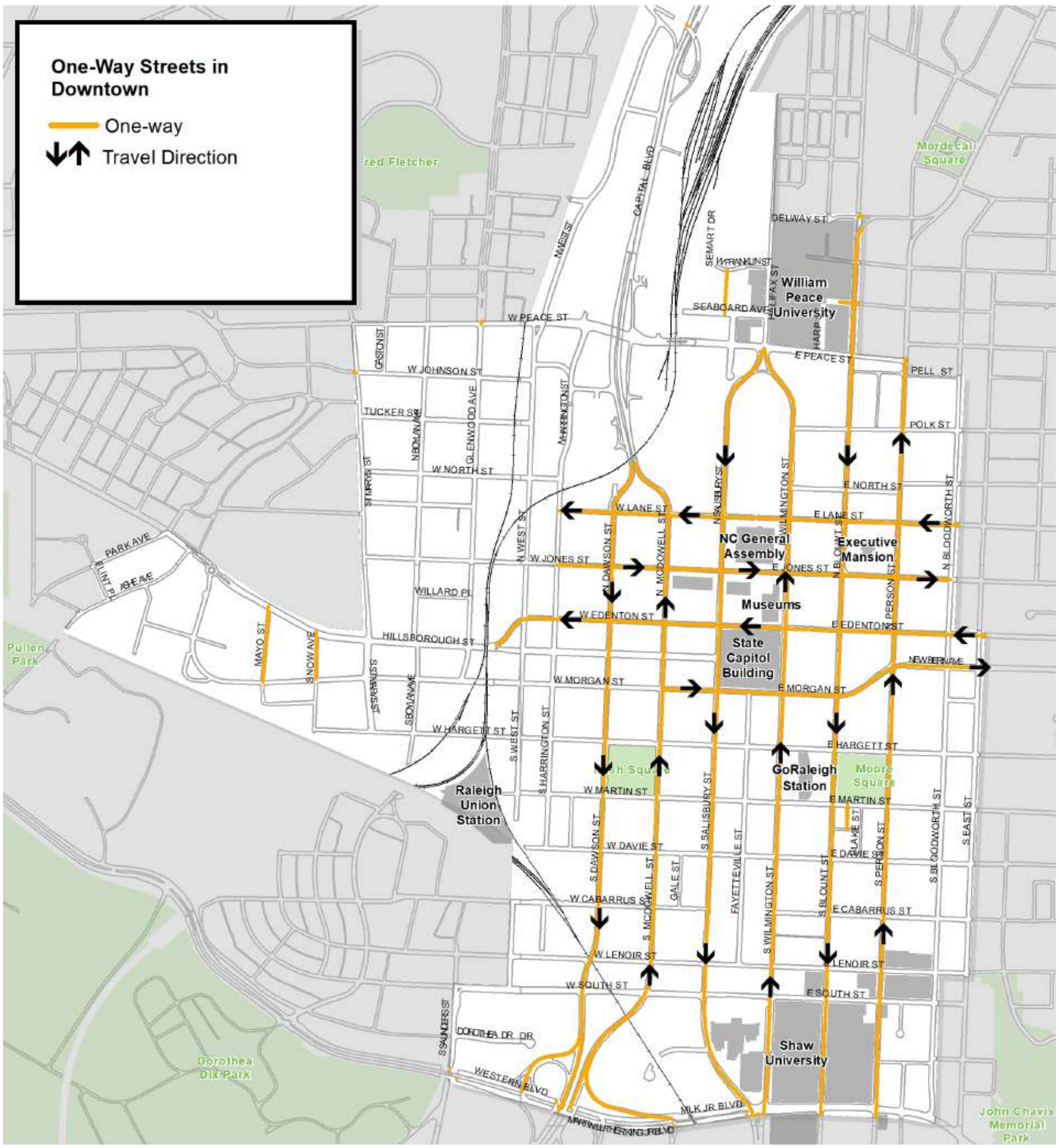
TABLE 7 — ADVANTAGES AND DISADVANTAGES OF ONE-WAY AND TWO-WAY STREET CONFIGURATIONS

Configuration	Advantages	Disadvantages	Recommendation for BRT
One-Way	▸ Faster speeds and progression benefits transit travel times ▸ Fewer turning conflicts for buses	▸ Reduced pedestrian and cyclist comfort with higher-speed traffic ▸ Routes being split on two different streets can be more difficult to understand for first-time users	Best for BRT and other bus operations due to increased speeds and reliability
Two-Way	Slower speeds can equate to higher comfort level for pedestrians	▸ Slower speeds for all buses compared to one-way configuration ▸ Small radii intersections in Downtown create difficulty for turning transit vehicles, especially right turns	Best where pedestrian comfort prioritized over bus speed and reliability

3.4.3 Recommendation

Generally, while advantages and disadvantages result from one-way versus two-way operation, BRT and other high-frequency transit service should be focused on one-way streets where possible within Downtown due to the importance of speed and reliability. Current bus operations in Downtown heavily utilize one-way streets for this reason, and BRT operations will place an even higher priority on speed and reliability. Figure 15 below shows the current one-way streets in Downtown Raleigh. Currently the City of Raleigh is planning to convert portions of the Blount/Person Street one-way pair, as well as the Jones/Lane Street one-way pair.

FIGURE 15 — ONE-WAY STREETS IN DOWNTOWN RALEIGH



3.5 Station Configuration for BRT and High Frequency Network

Due to the limited right-of-way availability, another key consideration in Downtown Raleigh will be how stations are configured to serve both BRT and High Frequency Network (HFN) services. Configuration options include:

- Shared BRT and HFN stations
- Separate BRT and HFN stations on same block
- Separate BRT and HFN stations on adjacent blocks

3.5.1 Option 1: Shared BRT and HFN Station

One option would be for BRT and HFN services to share a single location. If this option is used then it makes the possibility of a center-running BRT with a single center platform unlikely in Downtown, as this configuration would require left side doors for both BRT and HFN buses. The largest benefit of this option is that it makes transfers to and from the BRT service simpler, as all transit vehicles would arrive and depart from the same location. It also minimizes the amount of space needed for platforms in Downtown. Sharing a station also means amenities can be concentrated in one place, which reduces both capital cost of installation and maintenance cost when they are in operation. Similarly, shared stations have a relatively smaller impact to on-street parking and loading zones.

FIGURE 16 — RED LINE BRT LEVEL BOARDING STATIONS (APPLE VALLEY, MN)

There are a few drawbacks to sharing the same station space. One is that decisions about high and low platforms (and how high the BRT vehicle is from the ground) take on extra importance. BRT systems often utilize raised platforms to provide level or near-level boarding at the stations (see Figure 15), which reduces dwell time and streamlines BRT operations. Having the bus-station platform level with the bus floor is one of the most important ways of reducing boarding and alighting times per passenger. Passengers climbing even relatively minor steps can mean significant delay, particularly for the elderly, disabled, or people with suitcases or strollers. If raised platforms are utilized for the BRT stations in Downtown Raleigh, then HFN service would need to operate similar vehicles that can accommodate the raised platform height if they are to share station locations. Another option would be for the BRT to utilize standard low floor vehicles and standard sidewalk height platforms (see Figure 16) in order to share a single platform location with the HFN buses. While this would save on space Downtown, it would negate the benefit of level boarding for BRT vehicles and would require deployment of a ramp from the BRT vehicle or bus to the platform for ADA access (see Figure 17). Standard low floor vehicles and stations require more boarding time and can negatively impact travel times and reliability for BRT operations.

FIGURE 17 — A LINE BRT STANDARD HEIGHT PLATFORM (MINNEAPOLIS, MN)

FIGURE 18 — BRT WITH ACCESSIBLE BUS RAMP DEPLOYED

Further, a shared station could require additional supervision by GoRaleigh staff in order to maintain bus flow through the station, depending on the number of vehicles per hour expected at the platform. Small delays in boarding and alighting could prove problematic. For example, the Mid Term implementation in 2025, Wilmington Street could see 20 trips per hour in each direction (every 3 minutes) through the proposed station at South Street near Shaw University. At this frequency a small schedule disruption could result in delays with a single shared platform. Therefore, it is recommended that shared stations with a single platform only be employed where there are 15 or fewer trips per hour (one every 4 minutes). At higher frequencies it is recommended that at least two boarding platforms be provided.

3.5.2 Option 2: Separate BRT Station and HFN Stations on Same Block

A second option would be to locate BRT and HFN services on the same block, but in separate facilities. The benefits would be similar to option 1 – namely, that transfers between services would be fairly easy to accomplish. Further, option 2 would remove some of the issues with a shared station. The BRT and HFN stations could each be built to desired (and separate) standards. BRT could employ a high platform height while a nearby HFN stop could have a standard low-level platform. Operationally, the separation of stations allows for smoother operations and removes some of the need for street supervision.

The main disadvantage to option 2 is one of street space. Locating BRT and local stations on the same block will take up more urban space. The proposed BRT stations are assumed to be over 80 feet long and a HFN station could be an additional 30 to 50 feet long, depending on design. Blocks in Downtown Raleigh are typically a little over 400 feet in length, so two stations on the same block could take up a large portion of the block. Depending on the location, option 2 may also have more impacts to on-street parking or loading zones as well. Further, separating stations means more amenities (benches, shelters, etc.) would be duplicated across locations, resulting in an increase in both the capital and maintenance costs.

3.5.3 Option 3: Separate BRT Station and HFN Stations on Adjacent Blocks

A third option would be to locate BRT and HFN services on adjacent blocks in separate facilities. Many of the benefits outlined for option 2 also apply here. Transit operations would be smoothed so there would be no interference between BRT and HFN service. Station platforms could be built to the desired specification for both BRT and local service.

A further benefit of option 3 is flexibility in location of each station resulting from completely separating HFN and BRT stations. This means that stations will ultimately fit better within the street space in Downtown Raleigh, diminishing the impact in any one particular block resulting taking away on-street parking and loading.

The disadvantages of option 3 are similar to option 2. Station amenities would be duplicated across multiple locations, increasing both capital and maintenance costs. A further disadvantage is the time and distance for customers to transfer between BRT and HFN services. Placing stations on adjacent blocks increases the distance, which could be a deterrence. However, the short nature of Downtown Raleigh blocks means that walk distances between stations would be relatively short (ranging from around 200 to 700 feet). This is well within the normal bound for Downtown transfers. Wayfinding may need to be employed to help with the transfer.

3.5.4 Station Configuration Summary

Many factors will contribute to the location of BRT and HFN stations in Downtown Raleigh. Table 8 summarizes the advantages and disadvantages of the three options discussed.

TABLE 8 — ADVANTAGES AND DISADVANTAGES OF BRT AND HFN STATION LOCATION OPTIONS

Station Location Options	Advantages	Disadvantages
Option 1: Shared BRT and HFN Station	• Simpler transfer between services • Shared amenities result in lower capital and operating costs • Minimizes impact to on-street parking and loading areas	• Requires compromise on platform height/vehicle height (low vs high) • Can require street supervision to ensure shared operations • Limited trips per hour can be accommodated (generally less than 15 trips per hour)
Option 2: Separate BRT and HFN Stations on Same Block	• Allows for BRT and HFN platforms to be designed to unique specifications • Transfers between services still accomplished relatively easily • Can accommodate around 30 trips per hour	• Amenities for each station result in higher capital and operating costs • Potentially requires long stretch of street space in chosen block (relatively short blocks in Downtown Raleigh)
Option 3: Separate BRT and HFN Stations of Adjacent Blocks	• Allows for local and BRT platforms to be designed to unique specifications • Can accommodate around 30 trips per hour • Separation of stations allows for location flexibility in Downtown blocks	• Amenities for each station result in higher capital and operating costs • Transfers more difficult to achieve due to longer distance between stations

3.6 BRT Station Areas

BRT station areas were assumed in the vicinity of the following locations:

- GoRaleigh Station
- Raleigh Union Station
- Northern section of study area
- Southern section of study area

These station area assumptions were developed based on the concept that the proposed BRT routes should be routed to GoRaleigh Station and/or Raleigh Union Station to the extent possible. It was also established that other BRT station areas should be proposed within Downtown in addition to the ones at the transit hubs. It is assumed that the station area in the southern section of the study area would be located near Shaw University as this is a key destination in Downtown for many current transit riders.

4.0 Bicycle Network Phasing Strategy

Bicycle facility recommendations respond to both the BRT recommendations, previous bicycle planning efforts, and the desire expressed by the public and stakeholders for an enhanced bicycle system in Downtown. Recommendations include Tier 1 facilities (those that have both a vertical and horizontal separation between bicycle and auto traffic) and Tier 2 facilities (those without vertical separation). These recommendations would result in a significant increase in enhanced bicycle accommodations within the Downtown area.

The proposed implementation plan for the bicycle network seeks to achieve three main objectives:

1. Create a connected network that supports and provides connectivity to each phase of the BRT system.
2. Provide parallel facilities when the BRT infrastructure will remove an existing bike facility.
3. Avoid building isolated facilities by strategically identifying facilities that complement each other for continuous, connected trips through and around Downtown.

Table 9 below provides planning-level cost estimates for each bicycle facility type in the near-term, mid-term and full build-out phases. These costs need to be further refined at the project phases, however, now they provide a rough order of magnitude cost of funding required for each phase of implementation. An estimate of $200,000 per mile was assumed for Tier 1 facilities and an estimate of $50,000 per mile was assumed for Tier 2 facilities. These values were obtained from values provided by PeopleForBikes.org, and generally selecting the high end of the cost ranges provided for typical facilities. The only exception is the Lenoir Street Urban Trail (planned for the mid-term and full build-out phase) was estimated at $2,000,000 per mile based on the PeopleForBikes.org information along with local data from recent construction projects. In the mid-term phase, 0.25 mile of the Lenoir Street Urban trail is proposed to be built and in the full build-out phase the final 1.0 mile of the urban trail is proposed to be built.

TABLE 9 — PLANNING LEVEL COST ESTIMATES FOR PHASED IMPLEMENTATION OF BICYCLE NETWORK

Phase/Bicycle Facility Tier	Miles	Cost	Total Cost Per Phase
Near-Term Tier 1 Bicycle Facilities	4.3	$860,000	Near-Term: $960,000
Near-Term Tier 2 Bicycle Facilities	2.0	$100,000	
Mid-Term Tier 1 Bicycle Facilities*	3.7	$940,000	Mid-Term: $1,015,000
Mid-Term Tier 2 Bicycle Facilities	1.5	$75,000	
Full Build-out Tier 1 Bicycle Facilities*	3.8	$2,560,000	Full Build-Out: $2,675,000
Full Build-out Tier 2 Bicycle Facilities	2.3	$115,000	
Total Cost for Entire Bicycle Network: $4,650,000			

**Includes portions of Lenoir Street Urban Trail*

4.1 Near-Term Bicycle Network (2023)

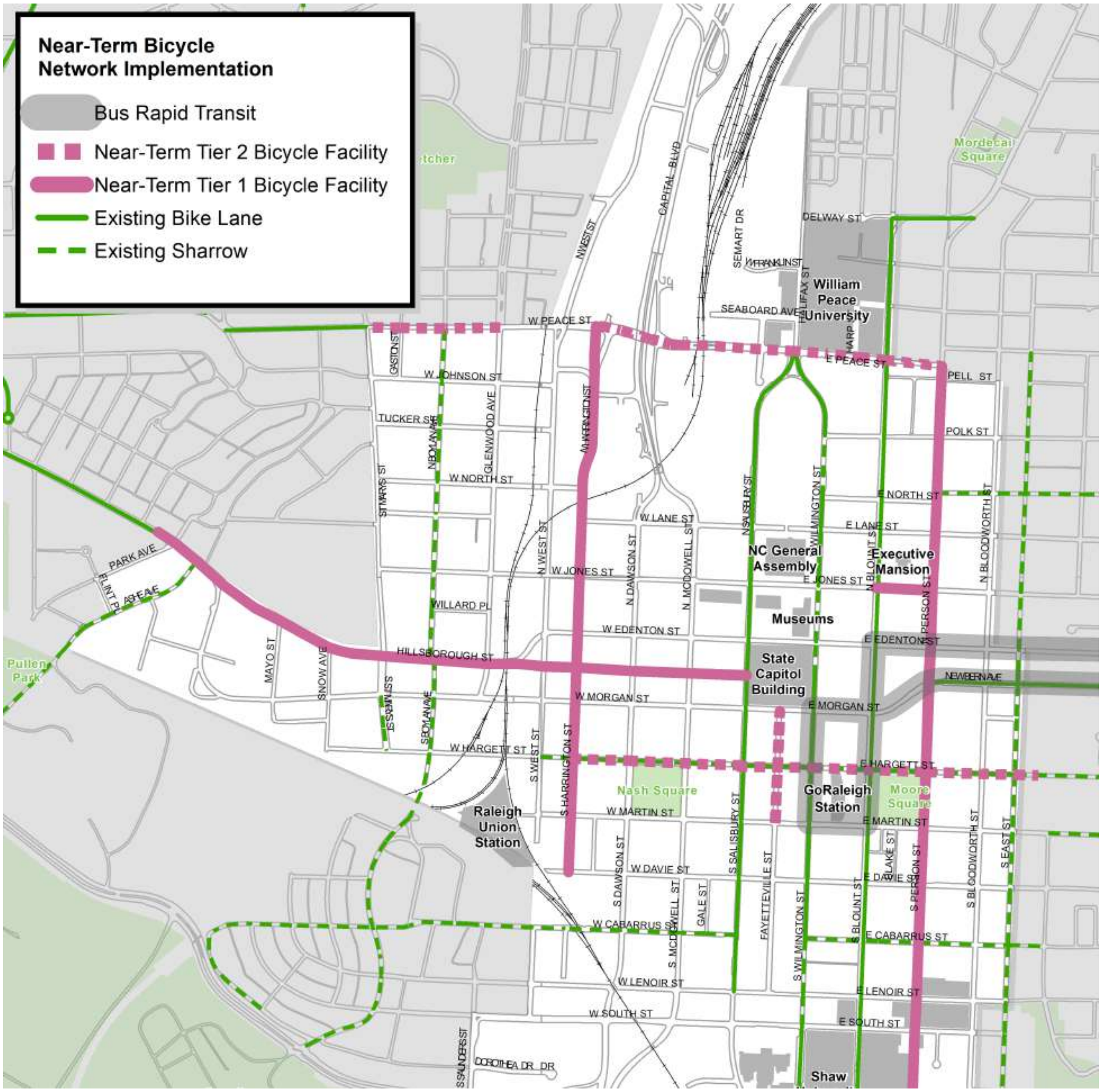
The near-term bicycle network was identified by incorporating a number of different factors including:

- Leveraging projects that already have momentum.
- Utilizing the existing bike network in Downtown.
- The goal of creating a "spine" of low-stress bike facilities that allow for north-south and east-west travel to and from the first phase of BRT.
- Impacts that the BRT implementation may have on existing bicycle facilities and where those existing facilities can be replaced.

The Tier 1 facilities on Harrington Street and Person Street are currently being designed and have funding momentum for implementation. These facilities provide key north-south connections on the east side (Person Street) and west side (Harrington Street) of Downtown and provide connectivity to Raleigh Union Station and Go Raleigh Station. Both of these facilities are recommended as two-way Tier 1 bicycle facilities. The two-way facility on Person Street would offset the BRT impacts on the proposed Blount Street bike lane that is planned to be installed prior to the BRT project.

Additionally, Hillsborough Street is a key connection to the west side of Downtown Raleigh. It is recommended that the existing bike lanes be converted to a parking-protected bike lane, which would have little to no impact on traffic operations and would enhance this important east-west connection to the center of Downtown.

FIGURE 19 — NEAR TERM BICYCLE NETWORK

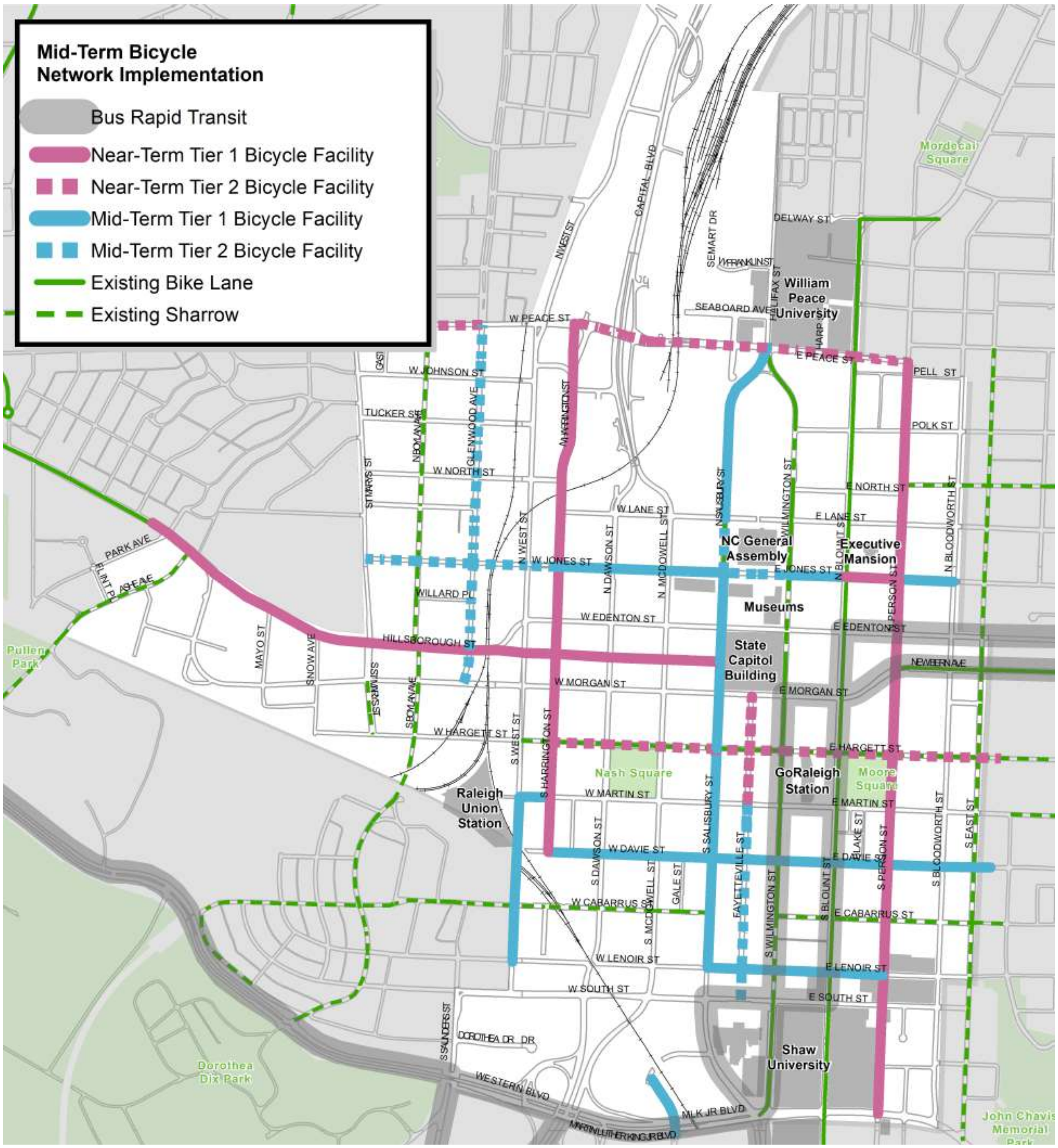


4.2 Mid-Term Bicycle Network (2025)

The mid-term phase of the bicycle network focuses on building off of the Hillsborough and Person Street separated bike lanes and strengthening access to those key facilities. The Jones Street and Davie Street Tier 1 facilities provide additional east-west access on the north side (Jones Street) and south side (Davie Street) of Downtown. The Salisbury Street Tier 1 protected bike lane and the Fayetteville Street Tier 2 bicycle facility provide alternative connections through the center of Downtown and offset the impacts to the existing bike lanes on Wilmington and Blount Streets caused by the mid-term BRT implementation.

Additionally, it is proposed that ¼-mile of the Lenoir Street Urban Trail be built during the mid-term phase to connect the Tier 1 facility on Salisbury Street to the Tier 1 facility on Person Street. Finally, the proposed Tier 2 facilities on Glenwood Avenue and Jones Street provide supporting facility connections to the Tier 1 facilities on Harrington Street and Hillsborough Street.

FIGURE 20 — MID-TERM BICYCLE NETWORK



4.3 Full Build-Out Bicycle Network (2027)

The final phase of implementing the full build-out of the full bicycle network fills in gaps of the previous phases and provides supporting facilities on the east side and northwest of the Downtown core area. The Tier 1 facilities along Boylan Avenue and Wilmington Street provide additional low-stress, north-south routes on the north side of Downtown. These facilities “feed” trips to the Hillsborough Street, Jones Street, and Salisbury Street Tier 1 facilities.

A key project recommended in this phase is completing the proposed urban trail along Lenoir Street. This trail provides key regional connectivity opportunities, including: the Chavis Greenway, the East Coast Greenway, the Art to Heart Trail, as well as major destinations such as Shaw University. The greenway proposed along Western Boulevard also provides a continuous connection along the south side of Downtown and provides key connections to destinations like Dorothea Dix Park and Pullen Park.

Based on the low-stress island analysis, the completion of the full build-out of the bicycle network will enable 96% percent of the Downtown study area to be accessible by bike on a continuous low-stress trip. For more information on the low-stress island analysis, see the Scenario Evaluation Report, (Volume II). The connected network will allow much of Downtown to be comfortable for most of the general population of bicyclists to navigate and will provide important regional connections. The full build-out network also plays a key role in the success of the BRT system by providing multimodal connections to the BRT corridors.

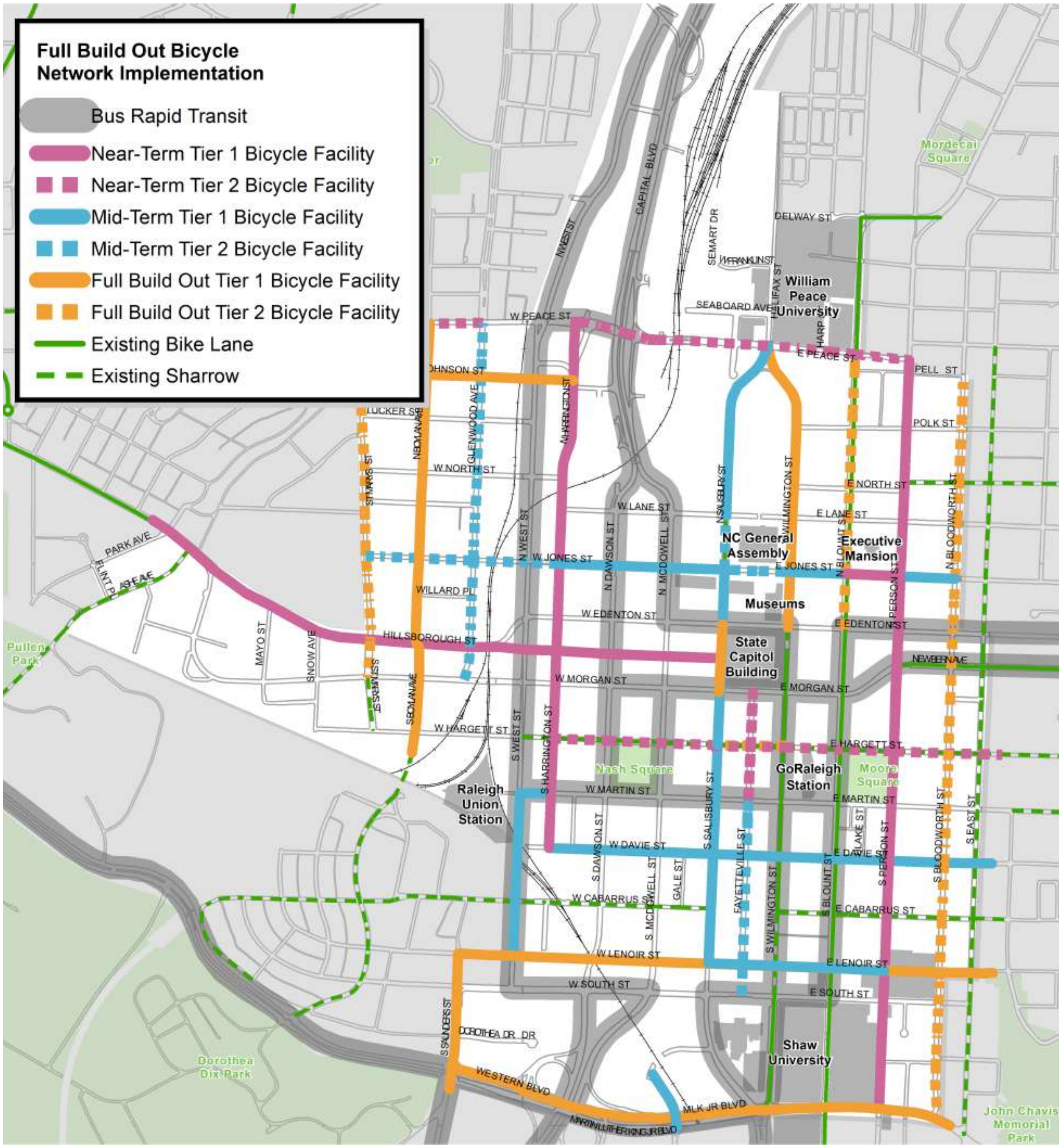
4.4 Bicycle Network Parking/Loading Zone Impacts

In order to determine the potential parking and loading zone impacts the following assumptions were made:

- Two-way cycle track width: 9’ bike lanes + 2’ buffer = 11’ total
- Parking protected bike lane width: 5’ bike lane + 3’ buffer = 8’ total (assumes it will replace on-street parking from the other side of the street and those are typically 8’ wide)
- Buffered bike lane width: 4’ bike lane + 2’ buffer = 6’ total
- Lenoir Street urban trail – assume 14’ absolute minimum, 16’ preferred

Based on these assumptions, it is assumed that 441 on-street parking spaces and 1,912 linear feet of loading zones would need to be removed to accommodate the near-term, mid-term and full build-out bicycle facilities. Additionally, there are a total of approximately 4,000 on-street parking spaces within the study area, so this would equate to an 11% reduction in on-street parking for all of Downtown. Lastly, there are approximately 24,000 total parking spaces within the study area (including on-street, surface parking, and parking decks) so this would equate to a 1.86% reduction in overall parking within Downtown.

FIGURE 21 — FULL BUILD-OUT BICYCLE IMPLEMENTATION



5.0 Bicycle Infrastructure Recommendations

The active transportation network for Downtown Raleigh includes both bicycle and pedestrian facilities. Pedestrian enhancement recommendations will be made in future streetscape plans. The proposed bike network provides recommendations for bike facilities that provide a connected network throughout Downtown, to the BRT stations and connect to the surrounding communities. The proposed bicycle facilities are categorized as Tier 1 and Tier 2 facilities. Tier 1 facilities are defined as physically separated bike lanes while Tier 2 facilities are defined as bike lanes, buffered bike lanes, and bikeways. The recommendations were informed by the Level of Traffic Stress (LTS) analysis completed earlier in the study, which measures the level of cyclist stress traffic characteristics, such as speed and volume, and a bicyclist on street experience. The recommendations leverage the LTS scores to select bike facilities that are comfortable for the general population.

The recommendations also consider how supporting facilities, such as buffered bike lanes and bikeways, can be strategically used to support access to the Tier 1 facilities. This is key to building out the network because if Tier 1 facilities are built without supporting facilities, they become isolated bike facilities and dilute the value of the high-investment projects. The recommendations of Tier 1 and Tier 2 facilities focus on creating a connected network the provides a continuous, low-stress trip to most places through Downtown that is comfortable for the general population. As described in the phasing plan, these active transportation recommendations provide the flexibility to relocate certain Tier 1 and Tier 2 facilities to parallel facilities to accommodate future BRT corridors while providing a connected bike network throughout Downtown.

5.1 Tier 1 Recommendations

All Tier 1 facilities recommended are either one-way protected bike lanes on one-way streets or one-way protected bike lanes in each direction on two-way streets. Exceptions include Harrington Street and Person Street, where spatial constraints may require different protected facilities, and Lenoir Street, where an urban trail is recommended.

Harrington Street and Person Street present spatial constraints which may make a one-way bike facility on both sides infeasible. A two-way cycle track on one side of the street requires 1-2 feet less overall space than one-way cycle tracks on each side, and can also be useful to provide two-way bike travel on one-way streets. Additional mitigation for driveways and intersections will need to be considered to manage the potential conflicts with two-way bike traffic at driveways and intersections. This mitigation can include:

- **Bicycle signals at intersections.** These are not necessary at every intersection along the corridor but can be targeted for use at intersections with high turning volumes or in locations where bicycle movements are unconventional or unexpected. The bicycle signal can be used to provide an exclusive bicycle phase to protect cyclists from conflicting vehicular traffic. See Figure 21.

FIGURE 22 — BICYCLE SIGNAL EXAMPLE

Source: NACTO Urban Bikeway Design Guide (Madison, WI)

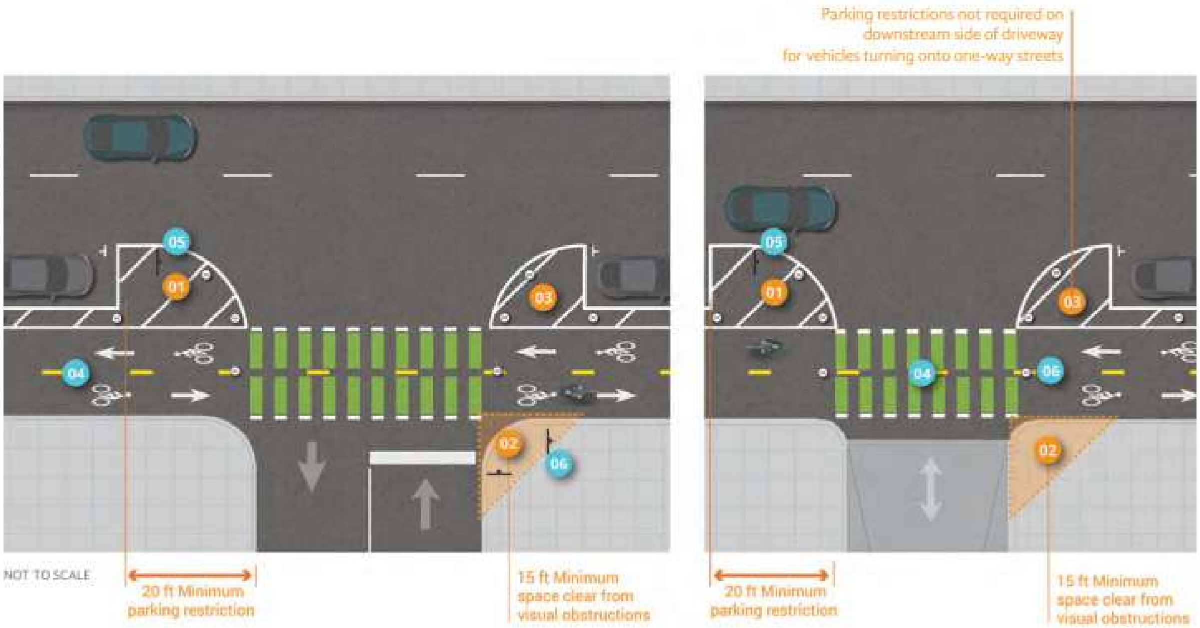
- **Bicycle detection with activated warning signs.** Bike detection can be placed in the bike lanes upstream of an intersection or driveway. When a bicyclist rides over the detection, it can trigger an activated warning sign for a driveway or a turning vehicle to alert drivers of on-coming conflicts. This can be used on one-way or two-way protected bike lanes that cross high-turning traffic volumes or high volume driveways. See Figure 22.

FIGURE 23 — BICYCLE DETECTION EXAMPLE

NE Broadway and N Williams Street, Portland, OR. The bicyclist triggers a detector upstream of the intersection where an activated warning sign is triggered and illuminated to warn right-turning drivers that a bicyclist is approaching the intersection.

- **Restrict parking on driveway approaches.** To provide adequate site distance for drivers as they make a turn into the driveway, parking should be restricted a minimum of 20-feet to see cyclists in the bike lanes on each side. This treatment also reduces the need for drivers to “inch out” into the bike lane in order to see oncoming traffic. See Figure 23.

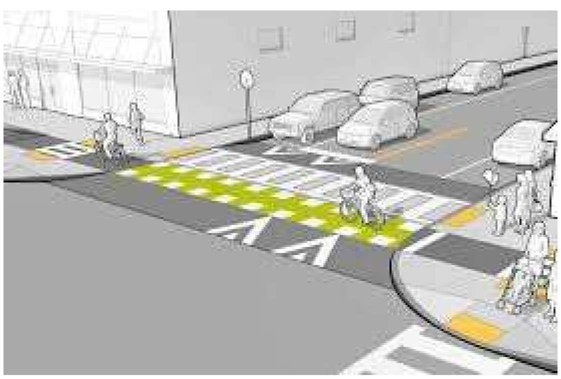
FIGURE 24 — PARKING TREATMENT AT DRIVEWAYS/INTERSECTIONS



Source: FHWA Separated Bike Lane Guide

- **Raised bike lanes.** Elevated bike lanes at intersections and driveways brings bicyclist up to driver eye level. The raised nature of the bike lane at the intersection also forces drivers to slow down as they anticipate going over the raised bike lane. See Figure 24.

FIGURE 25 — RAISED BIKE LANES EXAMPLE



Source: MassDOT Separated Bike Lane Design Guide

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- **Green paint at conflict points.** Green paint has been historically used to highlight potential conflict points between bicyclist and drivers at driveways and intersections. This provides an indication to drivers to expect bicyclists and to use extra caution when crossing the bike path. See Figure 25.

FIGURE 26 — PAVEMENT MARKINGS AT DRIVEWAYS/INTERSECTIONS

Source: NACTO Urban Bikeway Design Guide

An iconic urban trail is recommended on one side of Lenoir Street by widening the current sidewalk to a 14-foot to 16-foot shared use path that may include plantings, decorative pavement materials and art. An urban trail on Lenoir Street would provide a connection to the East Coast Greenway on the east and west side of the City. There is also a 6-block gap between the end of the Art-to-Heart Corridor (which ends at Lenoir Street and Fayetteville Street) and the Chavis Greenway. This trail would create a regional and neighborhood connection through Downtown and could become an iconic trail and corridor that feeds into the “civic spine” of Fayetteville Street. See Figure 26.

FIGURE 27 — URBAN TRAIL EXAMPLE

Source: Indianapolis Cultural Trail, by IndyLiving

5.2 Tier 2 Recommendations

The Tier 2 facilities recommended throughout the Downtown area include a combination of buffered bike lanes and bikeways. Buffered bike lanes are recommended for Peace Street, Salisbury Street between Jones Street and Lane Street, Jones Street between Wilmington Street and Salisbury Street, and Morgan Street between Wilmington Street and Salisbury Street.

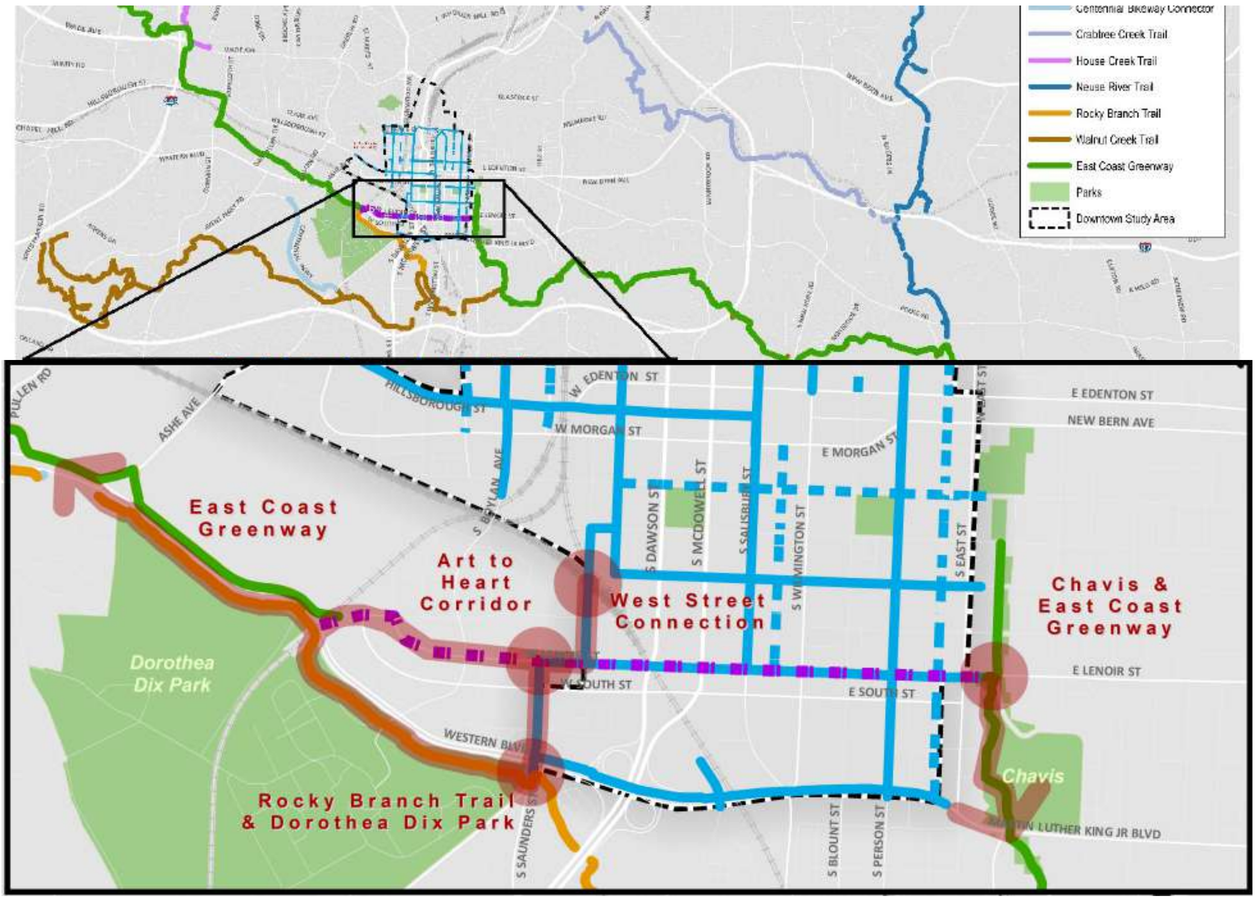
Bikeways are streets that are already considered low-stress, but sharrows and wayfinding signs can be used to communicate to drivers that bicyclist are expected on this street and communicate to bicyclist that this street has been identified as a priority for them. These streets can incorporate traffic calming measures such as bump outs at the intersection, narrowing the travel lanes and incorporating bike lanes as climbing lanes or contraflow lanes as the street width allows. On streets like Bloodworth Street and St. Mary's Street, additional traffic calming may be considered such as mini-roundabouts and bike-friendly speed humps. Through the Downtown area, signal progression that favors travel speeds of 12 mph to 15 mph may also be used to help manage traffic speeds on streets like Hargett Street and Glenwood Avenue.

5.3 Key Connections

While the recommendations are focused corridors in the Downtown, the proposed network has several key connection points that are critical to connecting the Downtown area and the BRT stations to key assets and communities outside of the Downtown area. These connections include:

- Continuing the Tier 1 Hillsborough Street facility so that it maintains a low-stress connection west of Downtown to N.C. State University.
- The construction of the West Street extension south under the railroad is a critical street to incorporate a low stress bicycle facility. This connection would enable a direct connection on the west side of Downtown to the Art-to-Heart corridor, the East Coast Greenway and Dix Park. Without this connection, bicyclists would need to divert over 7 blocks to have a continuous low stress trip to these facilities.
- The urban trail on Lenoir Street is a key regional connection to the Art-to-Heart Corridor and the East Coast Greenway. The trail also would provide a continuous connection from the Rocky Branch Trail to the Chavis Greenway, as well as a continuous east-west connection for the East Coast Greenway through Downtown Raleigh. See Figure 27

FIGURE 28 — LENOIR STREET URBAN TRAIL CONNECTIVITY



6.0 Bicycle and Transit Interaction Recommendations

Due to the possible high bus-bike conflict, recommendations for potential bike corridors was avoided on the same streets as BRT. This is because the width required to safely and comfortably design bike facilities on the same street as BRT is not feasible within the 66-foot right-of-way on most of Raleigh's Downtown streets. However, there are several streets where bus routes, in some cases, will be on the same corridor as a bike facility. For these corridors, design mitigations must be considered to manage how buses and bike interact at the bus stop. Section 6.1 summarizes recommended treatments for bike facilities at bus stops.

6.1 Bike–Transit Corridor Treatments

Additional guidance for each option includes:

- NACTO Transit Street Design
- AASHTO Guide for the Development of Bicycle Facilities
- NACTO Urban Bikeway Design Guide
- MassDOT Separated Bike Lane Design Guide

6.1.1 One-Way Buffered Bike Lanes Through Bump Out Bus Stop on Two-Way Street

Design Summary

Bike lanes are dedicated lanes, typically placed between a parking lane and travel lane or along a curb. Buffered bicycle lanes are on-street lanes that include an additional striped buffer of typically 2-3 feet between the bicycle lane and the vehicle travel lane and/or between the bicycle lane and the vehicle parking lane. A bike lane/buffered bike lane that continues through a bus stop, should have skip striping to indicate to both the bus driver and the bicyclist that they are entering a shared zone. The illustration shows a bus stop bulb out built to the edge of the parking lane to provide a larger bus stop area. This requires buses to partially block the travel lane while boarding and alighting passengers.

Typical Application

- Two-way street/one-way bike lanes
- Segments of the bicycle network with moderate vehicle speeds of 30 -35 MPH or volumes less than 8,000 ADT)
- Low frequency bus stops (< 6 buses per hour)

Design Considerations

Required:

- Bicycle lane width of 5-6 feet
- Additional buffer width of 2-3 feet
- Skip stripes indicating the conflict area between the bike lane and the bus stop is required.

Recommended:

- Green paint in the bike lane
- Bike sharrows through the bus stop area

Optional:

- BUS pavement markings in the bus stop
- Green backed Bike sharrows through the bus stop area

6.1.2 One-Way Buffered Bike Lanes Through Pull Out Bus Stop on Two-Way Street

Design Summary

Bike lanes and buffered bike lanes reach a conflict point at bus stops where buses are regularly pulling up to the curb. Especially when the bus frequency is high, and buses are expected to frequently block a bike lane and a travel lane, this conflict can be mitigated by providing a 13' wide bus pull out (8' parking lane and a 5' bike lane). This provides sufficient space for the bus to completely pull out of the travel lane and still provide a 5' space where an approaching bicyclist can go around the bus when it is stopped. This treatment does require bus drivers to check their driver side mirror for oncoming traffic and bicyclist before pulling out of the bus stop.

Typical Application

- Two-way street/one-way bike lanes
- Bus stops along arterials, collectors, and other non-local streets with speeds higher than 25 mph or over 3,000 average daily motorized traffic volumes
- High frequency bus stops (> 6 buses / hour)

Design Considerations

Required:

- Bicycle lane width of 5-6 feet
- Additional buffer width of 2-3 feet
- Skip stripes indicating the conflict area between the bike lane and the bus stop is required.

Recommended:

- Green paint in the bike lane
- Bike sharrows through the bus stop area

Optional:

- BUS pavement markings in the bus stop
- Green backed Bike sharrows through the bus stop area

6.1.3 One-Way Separated Bike Lanes Around Bus Stop on Two-Way Street

Design Summary

A separated bike lane is a bike lane that has a physical separation from traffic, such as flex posts, curb and/or a parking lane. Since the bike lane is positioned along the curb, it should be routed behind the bus stop (between the sidewalk and boarding area) to avoid the conflict between the buses and bikes at this location. This treatment eliminates leapfrogging between buses and bicyclist and increases bicyclist comfort and bus operating speed. For constrained conditions, the bike lane can be raised, and the bike lane and sidewalk can operate as a shared use path for the short distance behind the bus stop.

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Typical Application

- Two-Way Street/One-way Bike Lanes
- Bus stops along arterials, collectors, and other non-local streets with speeds higher than 25 mph or over 3,000 average daily motorized traffic volumes
- High frequency bus stops (> 10 buses / hour)

Design Considerations

Required:

- Bicycle lane width of 5 feet
- Boarding area must be designed to permit accessible boarding

Recommended:

- Bike lane can be raised to sidewalk level, where the bus stop area and sidewalk can share the bike lane space. Bicycle ramps should not exceed 1:8 slope. If raised, delineate bike and pedestrian space with paint or paving materials.
- At sidewalk level, the bike lane width may be narrowed to 4 feet, but 5 feet is recommended.

Optional:

- BUS pavement markings in the bus stop
- At bus stops with high ridership and pedestrian volumes, it may be necessary to require people on bikes to yield to people accessing the bus stop. Yield teeth and other markings and signs such as YIELD stencils and BIKES YIELD TO PEDESTRIANS (MUTCD R9-6) signs inform bicyclists of the requirement to yield to pedestrians.

6.1.4 One-Way Separated Bike Lane with a Bus Stop on One-Way Street

Design Summary

A separated bike lane is a bike lane that has a physical separation from traffic, such as flex posts, curb and/or a parking lane. When a one-way separated bike lane is on a one-way street with a bus route, the bike lane should be placed on the left side of the street. This removes conflicts with the bus stops on the right side of the street.

Typical Application

- One-way Streets with bus stops
- Driveway frequency should be considered
- Bus stops along arterials, collectors, and other non-local streets with speeds higher than 25 mph or over 3,000 average daily motorized traffic volumes
- High frequency bus stops (> 10 buses / hour)

Additional Guidance

- NACTO Urban Bikeway Design Guide
- AASHTO Guide for the Development of Bicycle Facilities
- NACTO Transit Street Design Guide
- MassDOT Separated Bike Lane Design Guide
- FHWA Separated Bike Lane

Design Considerations

Required:

- Bicycle lane width of 5 feet
- Additional buffer width of 2-3 feet
- A physical barrier, such as curb, flex posts, or planters must be installed in the buffer space to create physical separation between the bike lane and traffic.
- Skip stripes indicating the conflict area between the bike lane and driveways/intersections is required.
- Bus stop on right side of the street
- Bus stop uses parking lane for the bus to pull into.

Recommended:

- Bike lane can be raised to sidewalk level. If raised, delineate bike and pedestrian space with paint or paving materials.
- At sidewalk level, the bike lane width may be narrowed to 4 feet, but 5 feet is recommended.

Optional:

- BUS pavement markings in the bus stop

Additionally, it is expected that bike facility corridors will cross BRT corridors at several intersections throughout Downtown. Section 6.2 summarizes the treatments and elements of the intersection design when a buffered bike lane and separated bike lane crosses a BRT route.

6.2 Bike–Transit Intersection Treatments

6.2.1 Buffered Bike Lane Crossing BRT Routes

Description

When bike lanes cross at the intersection, the greatest risk is the right turn conflict point. This is where a right turning car turns into the bike lane and the driver has limited visibility of bicyclist on the passenger side of the vehicle. Bending the bike lane towards the curb and creating a pedestrian refuge forces right turning cars to slow down on their turns and places drivers in a position to see bicyclist as they are mid-turn before they cross the bike lane. This space is known as the "vehicle yielding zone." The pedestrian refuge also forces traffic on the side street to take a wider right turn which forces their natural path into the travel lane adjacent to the BRT lane.

As the bike lane continues through the intersection, green skip stripes increase visibility to the buses in the BRT lane that bicyclist are expected here. The BRT lane markings can also include skip stripes, and the bike lane markings can continue through one of the BRT skip stripe gaps.

Benefits

- Increases bicyclist visibily
- Reduces pedestrian crossing distance on side street
- Reduces right turn speeds
- Improves transit & bicyclist visibility to side streets and turning traffic
- Reduced cost of green and red paint through the intersection

6.2.2 One-Way Separated Bike Lane Crossing BRT Routes

Description

When cycle tracks cross at the intersection, the greatest risk is the right turn conflict point. This is where a right turning car turns into the bike lane and the driver has limited visibility of bicyclist on the passenger side of the vehicle. Restricting the parking approximately 20' back from the crosswalk and providing a pedestrian refuge forces right turning cars to slow down on their turns and places drivers in a position to see bicyclist as they are mid-turn before they cross the bike lane. This space is known as the "vehicle yielding zone."

As the bike lane continues through the intersection, green skip stripes increase visibility to the buses in the BRT lane that bicyclist are expected here. The BRT lane markings can also include skip stripes, and the bike lane markings can continue through one of the BRT skip stripe gaps.

Benefits

- Increases bicyclist visibility
- Continues protection through the intersection
- Reduces pedestrian crossing distance on side street
- Reduces right turn speeds
- Improves transit & bicyclist visibility to side streets and turning traffic
- Reduced cost of green and red paint through the intersection

7.0 Future Considerations and Recommendations

The Raleigh Downtown Transportation Plan provides a roadmap for implementation of a robust multi-modal network across the Downtown area. The outcome of other planning, design and funding initiatives will impact the exact location the multi-modal facilities. Specifically, the following factors will influence how the final Downtown transportation network evolves:

- The final alignments for the North and South BRT corridors, as laid out in the original Wake County Transit Plan, have not been finalized. The location of these corridors will impact the viability of different alternatives in the Full Buildout BRT Network in Downtown.
- The original Wake County Transit Plan called for commuter rail from Garner to Durham, including a stop at the Raleigh Union Station. Planning and design for commuter rail across the region is moving forward. Implementation of commuter rail service at Raleigh Union Station could impact the importance of certain BRT alternatives laid out in the Full Buildout BRT Network.
- In late 2018 GoTriangle, in partnership with the City of Raleigh and NCDOT received a $20 million federal BUILD grant from US DOT for construction of a bus transfer facility that will connect to Raleigh Union Station, also known as RUS Bus.
- The interchange of Western Boulevard/Martin Luther King Jr. Boulevard with Dawson and McDowell Streets is under consideration for reconstruction into a more urban, low-speed configuration that meshes better with the Downtown street grid. This reconstruction has the potential to provide good connectivity between the Downtown BRT network and the Western BRT corridor on Western Boulevard, but the ultimate design of the revised interchange has not been determined.
- The City of Raleigh is planning for the extension of West Street under the North Carolina Railroad tracks near Raleigh Union Station This extension is shown as a potential BRT route in the Full Buildout BRT Network. Full funding has not been identified for this extension, however, and as such the project cannot be assumed to be committed.
- As previously noted, the City of Raleigh is moving forward with redevelopment of the Raleigh Civic Campus block, including a potential redesign of Hargett Street into a pedestrian-priority urban plaza between the Civic Campus and Nash Square. This could have an impact on the viability of Hargett Street as a BRT corridor in this block.
- Various new developments have been recently constructed and are under construction within Downtown. These along with future developments may influence where BRT ultimately operate.

All of these issues and others will impact the final location of BRT corridors in Downtown Raleigh and should be taking into consideration as BRT is designed and implemented.