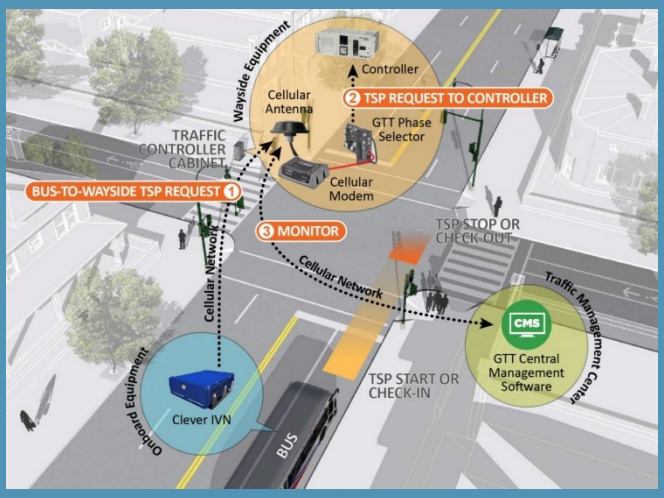
BUS PRIORITY BEST PRACTICES SYNTHESIS FOR THE NATIONAL CAPITAL REGION

November 2020



National Capital Region
Transportation Planning Board

BUS PRIORITY BEST PRACTICES SYNTHESIS FOR THE NATIONAL CAPITAL REGION
Prepared by Foursquare Integrated Transportation Planning for the Metropolitan Council of Governments
Adopted on Month Date, Year (if not officially adopted, just include a publish date)

ABOUT THE TPB
The National Capital Region Transportation Planning Board (TPB) is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. It is responsible for developing and carrying out a continuing, cooperative, and comprehensive transportation planning process in the metropolitan area. Members of the TPB include representatives of the transportation agencies of the states of Maryland and Virginia and the District of Columbia, 24 local governments, the Washington Metropolitan Area Transit Authority, the Maryland and Virginia General Assemblies, and nonvoting members from the Metropolitan Washington Airports Authority and federal agencies. The TPB is staffed by the Department of Transportation Planning at the Metropolitan Washington Council of Governments (COG).

CREDITS
Photo Credit: Metroway South Glebe Station, "Eye" Street Bus Lane (BeyondDC/Flickr), Components of TSP (Kimley Horn), Bus queue jump signal, 16th St DC (BeyondDC/Flickr)

ACKNOWLEDGEMENTS
Preprared by Foursquare Integrated Transportation Planning and ICF.

ACCOMMODATIONS POLICY
Alternative formats of this document are available upon request. Visit www.mwcog.org/accommodations or call (202) 962-3300 or (202) 962-3213 (TDD).

TITLE VI NONDISCRIMINATION POLICY
The Metropolitan Washington Council of Governments (COG) fully complies with Title VI of the Civil Rights Act of 1964 and related statutes and regulations prohibiting discrimination in all programs and activities. For more information, to file a Title VI related complaint, or to obtain information in another language, visit www.mwcog.org/nondiscrimination or call (202) 962-3300.

El Consejo de Gobiernos del Área Metropolitana de Washington (COG) cumple con el Título VI de la Ley sobre los Derechos Civiles de 1964 y otras leyes y reglamentos en todos sus programas y actividades. Para obtener más información, someter un pleito relacionado al Título VI, u obtener información en otro idioma, visite www.mwcog.org/nondiscrimination o llame al (202) 962-3300.

TABLE OF CONTENTS

FIGURES AND TABLES

EXECUTIVE SUMMARY

The Bus Priority Best Practices Synthesis is a resource for the National Capital Region (NCR) to provide local examples of bus priority projects as well as a comprehensive list of resources for planners and policymakers. Bus operators in the NCR provide over 164 million trips annually, and the vast majority of the population lives within a quarter-mile of transit. However, bus speeds and reliability have declined over the past decade, limiting residents' ability to access jobs and opportunities. Metrobus speeds, for example, have decreased by 9 percent or one mph over the past decade. Investing in bus priority treatments can improve bus speed, reliability, and efficiency. As a result, the system attracts new riders and improves the experience of existing ones, besides increasing the region's residents' access to jobs and opportunities.

The various bus priority treatments differ in terms of implementation costs, both financial and political, as well as their benefits. In this context, the synthesis highlights the results of previous and existing bus priority efforts in the NCR, including the Transportation Investments Generating Economic Recovery (TIGER) Bus Priority Project, the Bus Transformation Project (BTP), and other bus priority projects in the region. The synthesis also draws on existing literature to highlight the benefits and costs of bus priority projects as well as examples from other cities. The synthesis concludes with an overview of the costs and benefits of various bus priority treatments and ongoing and future projects in the NCR.

Types of bus priority treatments

This synthesis covers numerous bus priority treatments, ranging from on-road infrastructure, like dedicated lanes, to technological changes, like transit signal priority (TSP). The following provides definitions for the bus priority treatments highlighted in this synthesis and examples from the region.

Dedicated bus lanes/guideways are lanes restricted to buses by signage and/or pavement markings. These lanes could be separated from traffic, like the proposed K Street Transitway, concurrent with traffic, like the H and I Street bus lanes, contraflow lanes, or shoulder lanes. Bus lanes can be designated during peak periods only, or they can be a designated right-of-way for specific times.[i]

Transit Signal Priority (TSP) is a suite of tools that allows transit vehicles to communicate with traffic signals to adjust the signal phasing or timing, usually in the form of extending a green light for a few seconds or reducing a red light by a few seconds to allow for smoother transit operations[ii]. TSP requires sensors on buses, sensors embedded in the road and in signals, and a cellular network that connects the bus to the signal and a traffic management center[iii].

Queue Jumps are transit-only lane segments leading up to and at intersections that allow buses to "jump" over a queue of vehicles at a signal. Queue jumps are often used with other technology to allow a bus to enter an intersection before other traffic.[iv]

Parking limitations restrict parking for motorists either by charging or increasing the fee to park or reducing the number of parking spaces available. Reducing parking makes the use of a private vehicle more difficult, thereby amplifying transit.[v]

Stop consolidation reduces the frequency of stops a bus route makes, allowing for more efficient service.

Off-board fare payment allows riders to purchase tickets and pay for their ride before boarding the bus, decreasing boarding time at stops, and supporting the efficiency and reliability of bus transit.

2x

All door boarding works in conjunction with off-board payment, allowing riders to board through the rear door of a bus.

Results of TIGER Bus Priority in the NCR

Early investments in bus priority in the region came as a result of a TIGER grant. The US Department of Transportation (USDOT) awarded a $58.8 million TIGER grant to the National Capital Region Transportation Planning Board (TPB) for Priority Bus Transit in the National Capital Region in 2010.[vi] Five local governments or transportation agencies[vii] were responsible for carrying out the 16 individual component projects of the larger regional TIGER project, which were implemented through 2016. The improvements in technology and physical infrastructure aimed at making buses for reliable and convenient in the region. This synthesis presents the results of eight key corridors in which bus priority treatments included TIGER-funded dedicated bus lanes/guideways, TSP, or queue jumps.

Overall, TIGER-funded enhancements improved the reliability of bus routes and customer experience through more consistent travel times, access to service information, and upgraded transit facilities. Regarding the eight corridors with bus priority treatments that included bus priority treatments, the main findings can be summarized as follows. Passenger counts varied in line with service levels and region-wide changes for the vast majority of routes, and on-time performance improved significantly on two corridors across all time periods, and during off-peak periods on all corridors. A limited improvement during peak periods may be associated with more dynamic and heavier traffic during peaks. **Table 1** lists the corridors, their TIGER-funded bus treatments, and on-time performance improvements by time period.

Table 1: TIGER Bus Priority Key Findings by Corridor

Corridor	Bus Priority Treatment			On-Time Performance Improvement		
	Dedicated Lane	TSP	Queue Jump	AM Peak	Midday	PM Peak
16th Street NW, DC		✓	✓		✓	
Georgia Avenue NW, DC	✓	✓	✓		✓	
Wisconsin Avenue, DC		✓		✓	✓	
US 1 - Transitway, VA	✓			✓	✓	✓
VA 7 (Leesburg Pike), VA		✓		✓	-	
Van Dorn – Pentagon		✓	✓	✓	✓	✓
T. Roosevelt Bridge to K Street NW, DC*		✓		-	-	-
14th Street Bridge to K Street NW, DC*		✓		-	-	-

*T. Roosevelt Bridge to K Street and 14th Street Bridge to K Street corridors are treated as two separate corridors for performance monitoring and reporting, despite sharing the same bus priority enhancements in central Washington, DC. In addition to TSP, these corridors counted with signal optimizations at 197 intersections and uninterruptible power supply (UPS) at 30 locations.

Bus Transformation Project (BTP) recommendations

The Washington Metropolitan Area Transit Authority (WMATA)-led Bus Transformation Project was a collaborative, region-wide effort with the intent of focusing attention in the region on the importance of the NCR's bus network and the needs of its riders. Developed and shaped by a broad range of stakeholders and the public from across the NCR, the BTP developed a regional Strategy and Action Plan that focus on improving customer experience, connecting the region through better bus service, and fostering collaboration across transit and roadway agencies. The resulting Bus Transformation Project Strategy and Recommendations provides a vision for the future of bus transportation in the region, and the BTP Action plan provides a roadmap for carrying out the recommendations.

Key features of the plan are policy, capital, operating, and enforcement strategies that give bus priority on the roadways throughout the region. The plan highlights the need for transit agencies and roadway owners to work together to achieve the vision of moving people quickly and reliably, and details the following recommendations:[viii]

- Obtain commitments from state and local agencies (including roadway owners) to adopt consistent guidelines, bolster jurisdictional capital spending, and expedite coordinated implementation of bus priority.
- Implement enforcement policies that establish bus priority and result in reliable and fast service.
- Establish a capital program at WMATA that supports the accelerated implementation of bus priority projects, including BRT.

- Support regional congestion mitigation efforts that bolster bus priority and move more people more efficiently.

The bus priority treatments currently in effect in the region, as well as the bus priority projects currently under construction or in the early planning stages, help the NCR realize the vision set by the BTP.

Results of other bus priority plans, projects, and treatments in the NCR

Building off the success of TIGER projects in the region, several other bus priority projects have been implemented in the NCR since 2016, which are already seeing these results. The majority of these projects take a holistic approach to bus priority, providing a range of solutions to improve bus reliability in the region. Currently, operational projects in the NCR include:

- **The District Department of Transportation (DDOT) Bus Priority Program,** which is leading the agency's development of a Bus Priority Plan as well as identifying a pipeline of bus priority corridor projects in the District.
- **H and I Street** NW Bus Lanes were implemented in 2019 and have had a minor positive impact on bus speeds in those corridors.
- **Metroway,** the region's first BRT route, which consistently exceeds the ridership of the route it replaced, with a monthly ridership of 55,000 trips.
- **WMATA/DDOT TSP and Queue Jumps**, implemented at 179 intersections in the District and on four corridors in Alexandria, impacting 11 Metrobus routes. The treatments have improved schedule reliability, and, in non-downtown corridors, reduced scheduled runtime.
- **DDOT's Car Free Lanes**, a part of the District's COVID-19 Recovery that limit vehicle traffic on three corridors in the District.

Several additional bus priority projects are currently underway in the NCR to improve bus reliabtiliy and efficiency . The existing bus priority projects, as well as those under construction and in planning phases, help to carry forward the vision set forth by the BTP and will help connect NCR residents to jobs and opportunities.

Summary of expected benefits and costs by priority type

Implementing bus priority in the NCR requires significant investment, but adding bus priority treatments can have major positive impacts on bus reliability and efficiency, thereby improving the region's residents' access to jobs and opportunities; reducing costs; improving air quality; encouraging sustainable development; and improving the transportation system resliency. Bus priority treatments improve the experience for existing bus riders and can help attract new transit riders.

The specific benefits of each treatment vary based on the conditions in which the treatment is implemented; however, the examples clearly show that bus priority treatments work, especially when implemented in tandem with one another. That is, a dedicated lane implemented with all-door boarding and consolidated bus stops will have more positive benefits than a dedicated bus lane on its own.

Table 2 highlights a sample of bus priority improvements, their cost and degree of difficulty to implement, and the cost savings/performance improvements of each treatment.[ix] While lower-cost improvements provide some benefit and can be easier to implement, higher levels of investment can result in high-cost savings and/or performance improvements. The degree of difficulty highlights the level of effort required to implement a bus priority improvement; however, this metric varies based on site-specific considerations. While coupling treatments can result in more cost savings and performance improvements, the level of effort for implementation also grows.

Table 2 - Bus Priority Treatments and Impacts

Improvement	Improvement Description	Cost to Implement	Degree of Difficulty to Implement	Cost Savings/ Performance Improvements	Level of Anticipated Improvement
 TSP	Installed at some intersections, operated on a conditional basis	$0.3M to $9.0M per mile	Low to Moderate*	8% in travel time savings; $0.2M to $1.6M cost savings annually	Low
 Dedicated Lane	Dedicated lane on existing road	$0.2M to $1M per mile	Low	$0.25M in savings per year; 10-14% travel time savings, up to 27% increase in reliability	Moderate
 TSP and Queue Jumps	Dense network of TSP and queue jumps at some intersections	$0.3M to $20M per mile	Low to Moderate*	1-10% in travel time savings; $0.3M to $1.7M cost savings annually	Low
 TSP, Queue Jumps, Dedicated Lanes	Dense network of TSP, queue jumps at all intersections, dedicated lanes on the full route	$5.0M to $50M per mile	Moderate to High	18-54% in travel time savings; $0.55M to $1.95M in cost savings annually	Moderate to High
 TSP and Dedicated Guideway	Dense network of TSP, exclusive bus right-of-way	$30M to $80M per mile	High	18-66% in travel time savings; $0.55M to $1.8M cost savings annually	High

*TSP implementation can be costly and time consuming due to variations in technology and hardware

INTRODUCTION AND PURPOSE

Bus operators in the NCR provide over 164 million trips annually, and the vast majority of the population lives within a quarter-mile of transit. However, bus speeds and reliability have declined over the past decade, limiting residents' ability to access jobs and opportunities. Metrobus speeds, for example, have decreased by 9 percent or one mph over the past decade. Investing in bus priority treatments can improve bus speed, reliability, and efficiency. As a result, the system attracts new riders and improves the experience of existing ones, besides increasing the region's residents' access to jobs and opportunities. The various bus priority treatments differ in terms of implementation costs, both financial and political, as well as their benefits.

In this context, the Bus Priority Best Practices Synthesis is a resource for the National Capital Region (NCR) to provide local examples of bus priority projects as well as a comprehensive list of resources for planners and policymakers. The synthesis draws heavily from the Transportation Investments Generating Economic Recovery (TIGER) Bus Priority project, the Bus Transformation Project (BTP), and other bus priority projects in the region to illustrate the benefits and costs of bus priority types. It also pulls from literature and ongoing and completed planning efforts from cities across the United States.

This synthesis is broken down into several sections.

- **Results of TIGER Bus Priority in the NCR** provides an overview of the results of the region's TIGER projects.
- **Results of other bus priority in the NCR** highlights currently underway and recently completed bus priority projects in the region.
- **Bus Transformation Project (BTP) Recommendations** provides an overview of the bus priority recommendations and strategies from the Bus Transformation Project.
- **Key information from a literature review on the benefits and costs of bus priority** synthesizes the costs and benefits of implementing bus priority across numerous studies.
- **Key information from peers on the benefits and costs of bus priority** presents implemented bus priority projects from across the continent, highlighting benefits and costs.
- **Summary of expected benefits and costs of priority type** summarizes the expected costs and benefits of various priority types.
- **Future bus priority projects in the NCR** highlights currently underway bus priority projects in the region.

This synthesis covers numerous bus priority treatments, ranging from on-road infrastructure, like dedicated lanes, to technological changes, like transit signal priority (TSP). The following provides definitions for the bus priority treatments highlighted in this synthesis and examples from the region.

Dedicated bus lanes/guideways are lanes restricted to buses by signage and/or pavement markings. These lanes could be separated from traffic, like the proposed K Street Transitway, concurrent with traffic, like the H and I Street bus lanes, contraflow lanes, or shoulder lanes. Bus lanes can be designated during peak periods only, or they can be a designated right-of-way for specific times.[x]

Transit Signal Priority (TSP) is a suite of tools that allows transit vehicles to communicate with traffic signals to adjust the signal phasing or timing, usually in the form of extending a green light for a few seconds or reducing a red light by a few seconds to allow for smoother transit operations.[xi] TSP requires sensors on buses, sensors embedded in the road and signals, and a cellular network that connects the bus to the signal and a traffic management center.[xii]

Queue Jumps are transit-only lane segments leading up to and at intersections that allow buses to "jump" over a queue of vehicles at a signal. Queue jumps are often used with other technology to allow a bus to enter an intersection before other traffic.[xiii]

Parking limitations restrict parking for motorists either by charging or increasing the fee to park or reducing the number of parking spaces available. Reducing parking makes the use of a private vehicle more difficult, thereby amplifying transit.[xiv]

Stop consolidation reduces the frequency of stops a bus route makes, allowing for more efficient service.

Off-board fare payment allows riders to purchase tickets and pay for their ride before boarding the bus, decreasing boarding time at stops, and supporting the efficiency and reliability of bus transit.

2x

All door boarding works in conjunction with off-board payment, allowing riders to board through the rear door of a bus.

RESULTS OF TIGER BUS PRIORITY IN THE NCR

The US Department of Transportation (USDOT) awarded a $58.8 million TIGER grant to the National Capital Region Transportation Planning Board (TPB) for Priority Bus Transit in the National Capital Region in 2010.[xv] Five local governments or transportation agencies[xvi] were responsible for carrying out the 16 individual component projects of the larger regional TIGER project (**Table 3**), which were implemented through 2016. The improvements in technology and physical infrastructure aimed at making buses more reliable and convenient in the region.

Table 3: List of TIGER Projects in the NCR and Grant Award

Project Number	Project Name	Location	Grant Award
2	16th Street Bus Priority Corridor Enhancements	DC	$1,295,000
3	Georgia Avenue Bus Priority Corridor Enhancements	DC	$4,111,000
4	H Street/Benning Road Bus Priority Corridor Enhancements	DC	$415,000
5	Wisconsin Avenue Bus Priority Corridor Enhancements	DC	$745,000
6	Addison Road Bus Priority Corridor Enhancements	MD	$200,000
7	University Boulevard Bus Priority Corridor Enhancements	MD	$1,262,000
8	US 1 (MD) Bus Priority Corridor Enhancements	MD	$805,000
9	Veirs Mill Road Bus Priority Corridor Enhancements	MD	$265,000
10	US 1 (VA) Transitway	VA	$8,500,000
11	VA 7 (Leesburg Pike) Bus Priority Corridor Enhancements	VA	$1,340,000
12	Van Dorn – Pentagon Bus Priority Corridor Enhancements	VA	$670,000

Project Number	Project Name	Location	Grant Award
13	T. Roosevelt Bridge to K Street Bus Priority Corridor Enhancements	DC	$1,800,000
14	14th Street to K Street Bus Priority Corridor Enhancements	DC	$5,200,000
16a	Pentagon – Franconia-Springfield Station Improvements	VA	$9,930,000
16b	PRTC Buses and ITS Technology	VA	$10,000,000
18	Takoma/Langley Transit Center	MD	$12,300,000
		Total	$58,838,000

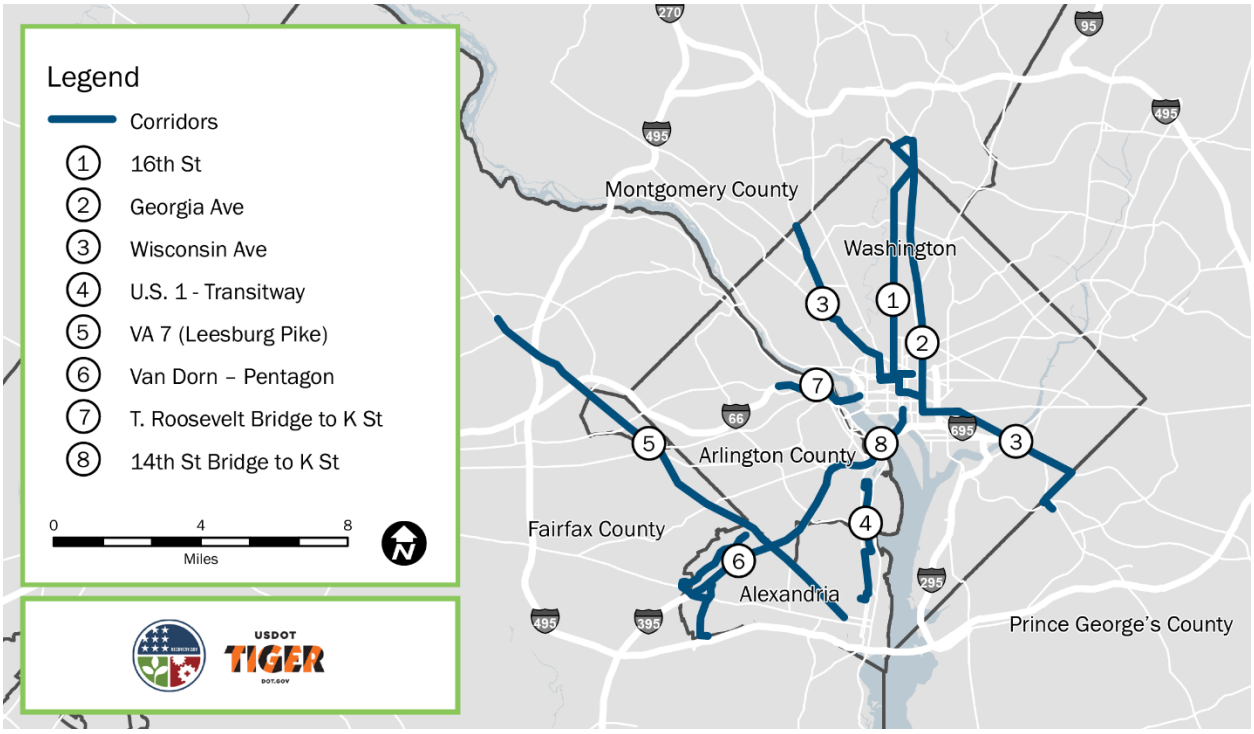
TIGER-funded improvements included a new transit center, vehicle ITS technology, station and bus stop improvements, real-time passenger information signs, as well as dedicated bus lanes, TSP, and queue jumps. This synthesis highlights the three last enhancements as bus priority treatments and further discuss their impacts. **Table 4** lists the TIGER-funded bus priority treatments on eight key corridors connecting major residential, commercial, and employment centers in the NCR, and **Figure 1** shows the location of each corridor.

Table 4: TIGER Bus Priority Corridor Enhancements by Corridor

Corridor	Dedicated bus lanes/ guideways	Transit Signal Priority (TSP)	Queue Jumps
16th Street, DC	-	31	1
Georgia Avenue, DC	0.3 mi	57	3
Wisconsin Avenue, DC	-	39	-
US 1 - Transitway, VA	0.8 mi	-	-
VA 7 (Leesburg Pike), VA	-	25	-
Van Dorn – Pentagon	-	9	2
T. Roosevelt Bridge to K Street, DC*	-	68**	-
14th Street Bridge to K Street, DC*	-	68**	-

*T. Roosevelt Bridge to K Street and 14th Street Bridge to K Street corridors are treated as two separate corridors for performance monitoring and reporting, despite sharing the same bus priority enhancements in central Washington, DC.
**In addition to TSP, these corridors counted with signal optimizations at 197 intersections and uninterruptible power supply (UPS) at 30 locations.

Figure 1: TIGER Bus Priority Corridors in the NCR



Reports on the performance of the TIGER funded projects were required for each of the 16 projects funded by the grant, including a report one year before projects begin, and reports one and two years after project completion. These reports presented a set of applicable metrics, depending on the type of improvement, to assess the results of the bus priority enhancements on each corridor. At a minimum, reports included an analysis of transit service level and passenger counts for the routes on the corridor, while the most comprehensive reports would include:

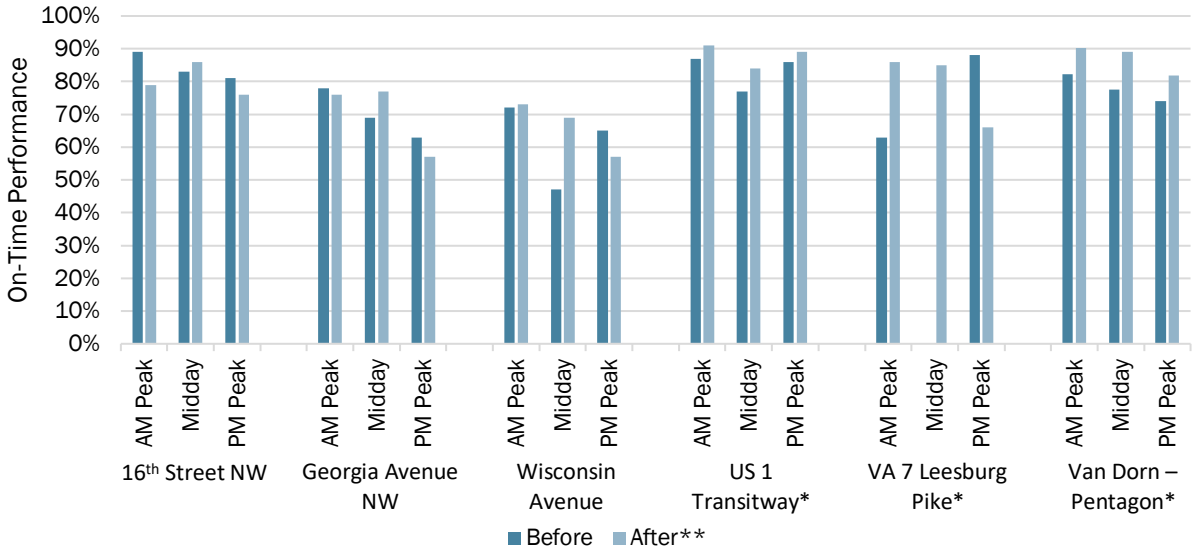
- Transit Service Level
- Passenger Counts
- Passenger Counts / Average Load
- On-Time Performance
- Vehicle Travel Time for Corridor
- Passenger Miles for Corridor
- Passenger Hours of Travel for Corridor
- Transit Rider Characteristics

For the reporting, the section of roadway between the first and last improvement was called an implementation corridor. Only bus routes that travel on 50 percent or more of the implementation corridor were included and classified into two types: priority and non-priority bus routes. A priority bus route is a Metrobus priority or limited-stop bus route, generally branded as MetroExpress or MetroExtra. All other routes included in the reports were viewed as non-priority bus routes. The priority bus routes would be able to take full advantage of the improvements to bus travel time. In contrast, the non-priority routes might not have the right technology or have too closely spaced stops to be able to utilize all improvements.

The selected metrics and reporting format had limited success in capturing the impact resulted from TIGER-funded improvements in the NCR. With up to eight years between the before and after reports, multiple routes were excluded, created, or experienced significant changes, making the route-to-route comparison difficult. At the corridor level, significant shifts in levels of service, travel conditions, and ridership also limit evaluations of the impacts. However, the vast majority of the routes presented ridership variations aligned with the level of service or sector and region-wide changes. Ultimately, despite the limitations in performance monitoring and reporting, TIGER-funded enhancements improved the reliability of bus routes and customer experience through more consistent travel times, access to service information, and upgraded transit facilities.

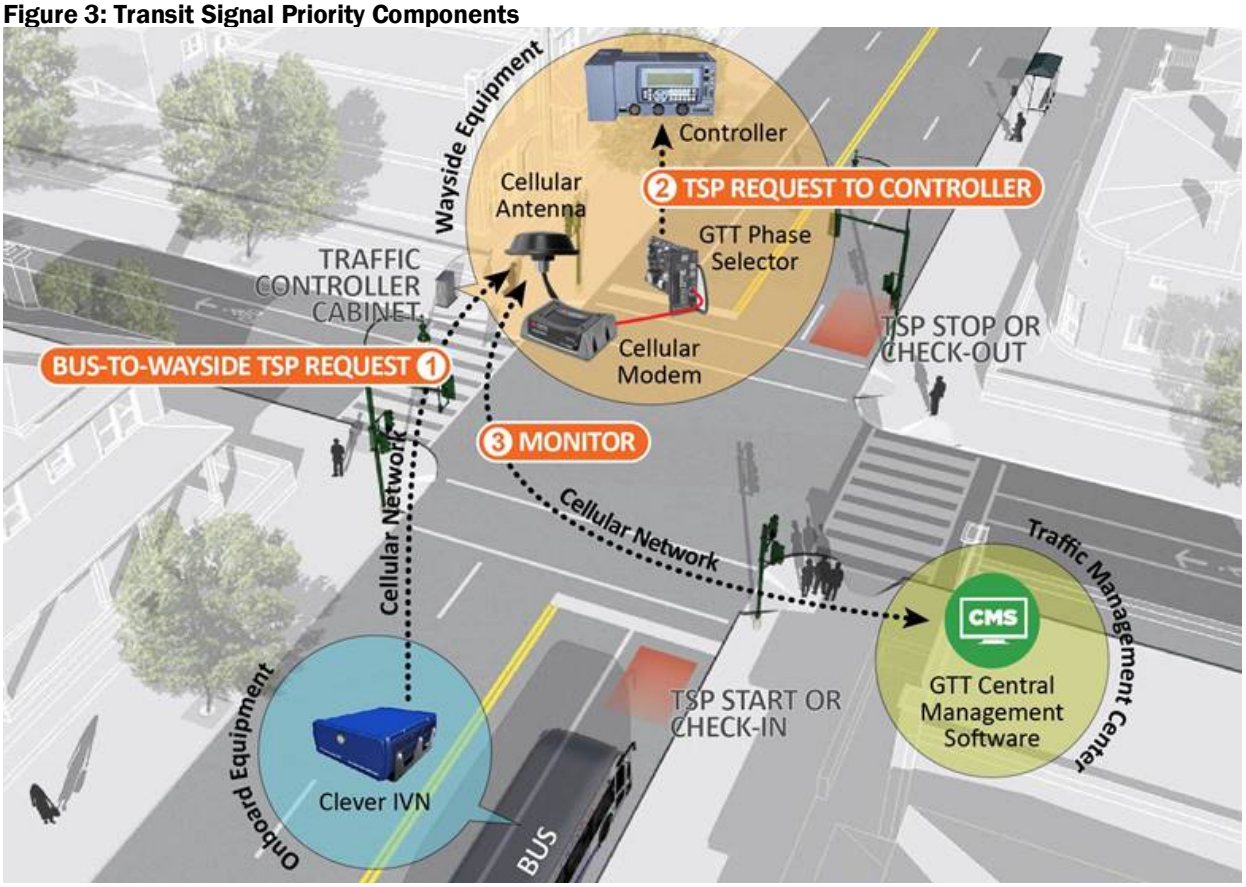
Regarding specific metrics, the changes in on-time performance varied between corridors and time periods, and TSP refinements between report periods impacted the comparison of travel time on corridors. On-time performance improved across all time periods on US 1 Transitway and Van Dorn – Pentagon corridors, while the other corridors showed improvements limited to midday periods, as can be seen in **Figure 2**. TSP was the most common TIGER-funded enhancement, and, in addition to physical components illustrated in **Figure 3**[xvii], it requires a set of parameters that will define if any traffic signal action is triggered. These parameters may include a lateness threshold or load factors and were refined during the reporting period. Despite these refinements and potentially impacted by the more dynamic and heavier peak period traffic, on-time performance and travel time improvements were greater during off-peak periods. Next, the main findings are organized by corridors with dedicated bus lanes/guideways, or TSP or queue jumps enhancements.

Figure 2: WMATA priority routes on-time performance before and after TIGER-funded enhancements



*OTP average of all WMATA routes on the corridor.
**After measures are of two years after the enhancement implementation.

Figure 3: Transit Signal Priority Components



Source: Kittelson & Associates, Inc.

TIGER Bus Priority Key Findings

16TH STREET NW, DC

The corridor experienced shifts in levels of service, including an increase of 181 priority route trips, and a decrease of 185 non-priority route trips, resulting in a net loss of four trips. Weekday average headway on the corridor remained mostly stable and was reduced by more than 5 minutes only in the midday time period. The overall decrease in ridership on the corridor mirrors ridership patterns in the Washington Metropolitan Area Transit Authority's (WMATA) Central DC Sector. On-time performance decreased on Route S9 during weekday peak periods but increased midday. TSP improvements may have mitigated the effects of congestion and boosted reliability on Priority Route S9, although trends in travel time and on-time performance were unclear.

GEORGIA AVENUE NW, DC

While the impact of the Georgia Avenue bus priority improvements is difficult to observe in changes in ridership, it is likely that the implementation of dedicated bus lanes, transit signal priority, and queue jumps affected vehicle travel time and reliability. Vehicle travel time showed an increase for all time periods on the corridor, although the difference between scheduled and actual travel time was reduced. Improved schedule adherence may be a result of TSP and queue jumps along with improved scheduling practices. Regarding on-time performance, priority Route 79 in particular consistently met WMATA's minimum standard of 79 percent on-time arrivals on weekends and had the best weekday performance during the morning peak and midday among routes on the corridor.

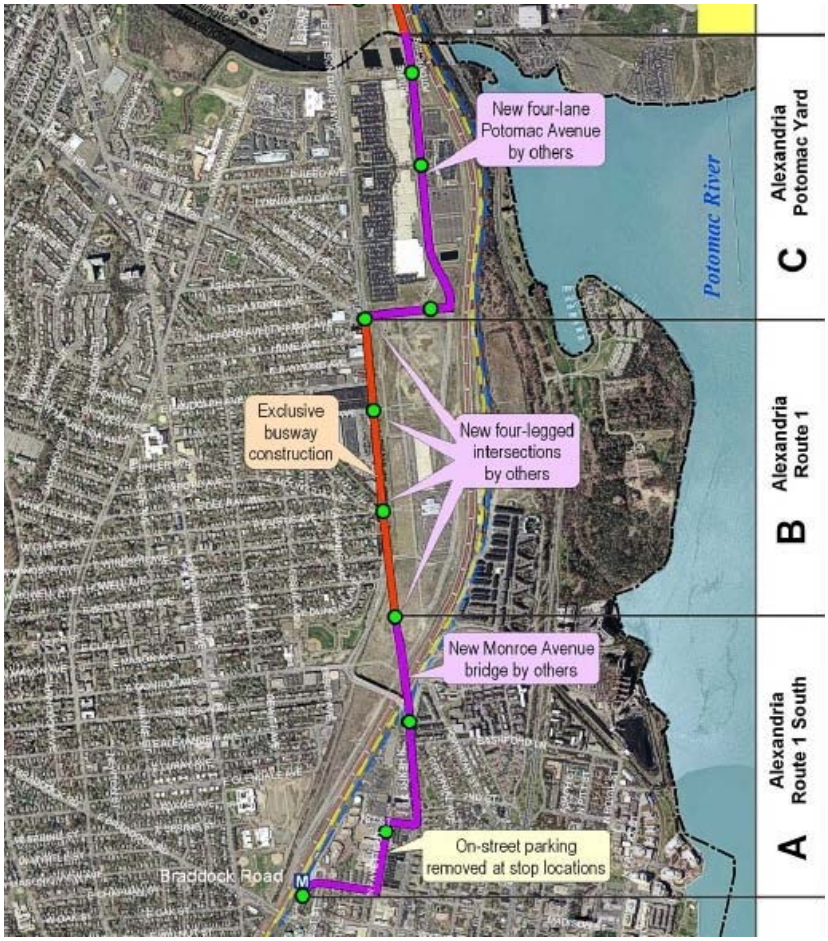
WISCONSIN AVENUE, DC

On-time performance improved in AM Peak and Midday time periods for both Route 37 and 39, the two MetroExtra routes on the corridor. These routes may have benefitted from new transit signal priority, but on-time performance remained below WMATA standards in all periods. TSP improvements may have mitigated the effects of congestion and boosted reliability on Route 37, although trends in travel time and on-time performance were unclear. In terms of total ridership, the routes on the corridor behaved similarly to others in their service sector.

US 1 – TRANSITWAY, VA

The US 1 Transitway Bus Priority Improvement Project funded the construction of a 0.8-mile segment of dedicated transitway. As depicted in Figure 4, this project implemented segment B of the bus transitway, from East Glebe Road to Potomac Avenue, utilizing the median of US 1 to create the bus transitway and offer exclusive right-of-way for buses. The lanes allow transitway bus users to avoid traffic congestion while providing convenient access to the Potomac Yard development.

Figure 4: US-1 Transitway Enhancements Map



Following the TIGER-funded first segment of transitway, the Metroway project included phases that eventually included an enhanced bus service between Braddock Road and Pentagon City – the region's first Bus Rapid Transit (BRT)-type bus route. Overall, the project had a significant positive impact on transit ridership on the corridor, especially during peak hours. Equally as important, the on-time performance of routes serving the US 1 corridor markedly improved, primarily due to the new Metroway service consistently exceeding WMATA performance standards. In a passenger survey conducted during the 1st After Report period (from August 2014 to July 2015), results also showed that:

- Metroway attracts high-income choice riders; 57 percent of riders surveyed earn $100,000 or more, and 84 percent of riders surveyed have at least one car at home.
- Metroway is a link to other modes of transit; 38 percent of all trips include a connection to other public transit. The most used public transit service is Metrorail (23 percent of all Metroway trips).
- The majority of riders are satisfied with the service; on a scale of 0-10, 74 percent rank Metroway as seven or higher.
- Most dissatisfaction is in the frequency of buses, which has 37 percent of riders either unsatisfied or neutral. Fifty-three written comments also mentioned the need for improvement in the frequency of buses.

- In the written comments, 27 riders noted that arrival information was incorrect and that electronic signage on buses was incorrect, which was not a question asked under the satisfaction question.

Taken together, the transitway improvements have had a significant positive impact on the quality of transit service on the US 1 corridor, and consequently, ridership levels and rider satisfaction.

VA 7 – LEESBURG PIKE, VA

During the reporting period, large changes in levels of service occurred on the corridor, including an increase in the number of trips that resulted in shorter average headways. Revenue miles and hours also increased by roughly 50 percent. On-time performance improved for both priority and non-priority routes, indicating a possible effect of transit signal priority.

VAN DORN – PENTAGON, VA

The Van Dorn – Pentagon project added queue jumps and TSP affecting five WMATA routes and two Driving Alexandria Safely Home (DASH) routes. There are some indications that the improvements to the corridor had a positive impact on the transit level of service and performance. In particular, improvements to the study routes' on-time performance suggests that the enhancements allowed transit vehicles to run efficiently and reliably, despite worsening traffic congestion in the region.

The majority of routes improved their on-time performance and either maintained high levels or followed an upward trend after bus priority improvements. On-time performance on the corridor was almost always above 80 percent, and often much higher. Widespread improvements in on-time performance could, in part, be the result of the queue jumps and transit signal priority treatments installed as part of this project. However, increases in revenue hours, along with constant revenue miles, suggest slower transit travel speeds on the corridor.

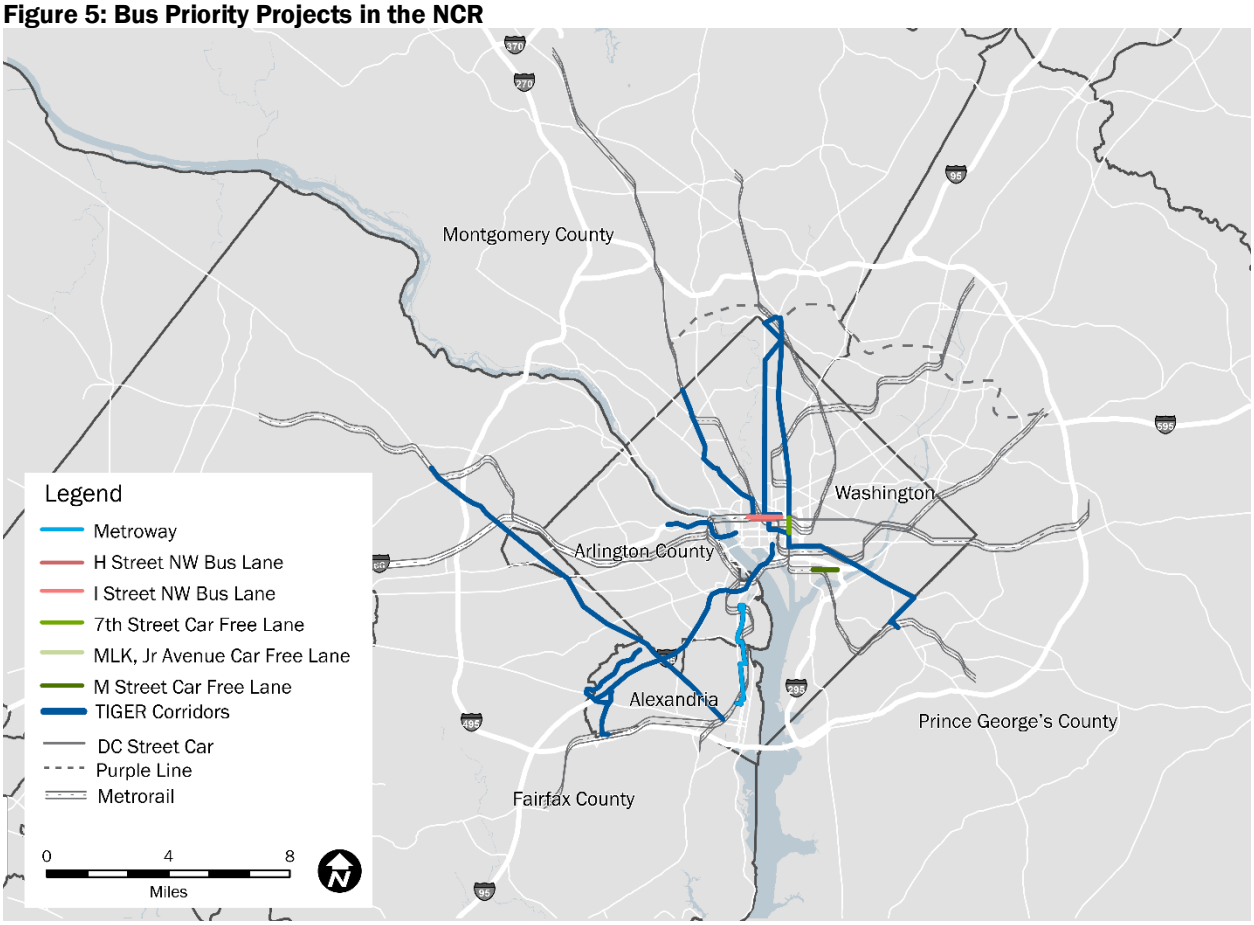
T. ROOSEVELT AND 14TH STREET BRIDGES TO K STREET NW, DC

The project optimized traffic signals in 197 intersections, installed transit signal priority systems in 68 intersections, and installed uninterruptable power supply units for signals in 30 intersections. Due to the number of transit providers and bus routes crossing both bridges, the performance metrics common to all and evaluated in the reports were level of service and passenger counts. TIGER-funded signal improvements likely improved the reliability of bus routes along the corridor. However, eliminated bus stops, alignment changes, and the addition of bus routes since 2010 make it difficult to measure the impacts of TIGER improvements on service operations and associate the changes in the level of service and ridership.

RESULTS OF OTHER BUS PRIORITY PLANS, PROJECTS, AND TREATMENTS IN THE NCR

The NCR has undertaken numerous bus priority projects, many of which are already seeing results. The majority of these projects take a holistic approach to bus priority, providing a range of solutions to improve bus reliability throughout the region. The following sections highlight bus priority projects in the NCR that are currently operational. Additional projects that are under construction or in the early planning stages are included at the end of this report in the **Future bus priority projects in the NCR** section. The existing bus priority projects in the region are shown in **Figure 5**.

Figure 5: Bus Priority Projects in the NCR



WMATA/DDOT TSP and Queue Jumps[xviii]

Transit Signal Priority (TSP) was first implemented in the District and select Northern Virginia jurisdictions in 2016 through the region's TIGER grants. While different controllers may require different equipment with different system requirements, most require on-board equpement, wayside equipment, and a connection to a traffic management center. Euipment includes both hardware and software.

Today, TSP operates in the District at 179 intersections along 11 Metrobus routes (37, S9, 79, 3Y, 11Y, 16C, 16Y, 7Y, 39, 54, and 59). In addition to the TSP network in the District, four corridors in Alexandria, Virginia (Seminary Road, Duke Street, Van Dorn Street, and Beauregard Street) are equipped with TSP. The City was also awarded funding to outfit DASH buses with TSP technology. A project to expand TSP to King Street is currently underway. [xix]
The corridors on which TSP operates were chosen in part because of known modal challenges due to the collectively high auto, pedestrian, and bus volumes. WMATA and DDOT have worked collaboratively over the last two years to review, assess, and improve the effectiveness of these TSP intersections to improve bus service reliability and runtimes along these corridors.

Preliminary findings of the review show that while performance improvements vary considerably by bus route segment, TSP was found to improve schedule reliability and, in non-downtown corridors, reduce schedule runtime. For example, for Metrobus S9 on less congested areas of 16th Street NW, TSP was found to improve overall service reliability, highlighted by reductions in the 95th-percentile

schedule deviation of more than 50 percent. Further, TSP in those sections was successful in reducing bus runtimes by up to 12 percent. On the other hand, in congested areas downtown, TSP was not proven effective in improving bus runtimes.

DDOT and WMATA's testing also examined the TSP "parameter" settings that trigger an extended green or shortened red, such as delay relative to schedule or passenger loadings. That research found that less restrictive parameters help to increase the number of buses that can benefit from TSP while also incrementally improving average bus runtimes and runtime reliability.

Importantly, in no case did this joint testing exercise show TSP to adversely affect congestion or performance of other modes. In light of these findings and continued interest in improving bus operations, WMATA, in coordination with DDOT as well as other local jurisdictions in Virginia and Maryland, is continuing to monitor the effectiveness of the existing system and explore options to enhance and expand the TSP network.

Metroway

Building off TIGER funded bus priority improvements, described in **Results of TIGER Bus Priority in the NCR**, Metroway (Figures 6 and 7) is the region's first BRT route. Service. WMATA has operated Metroway since 2014 between the Pentagon City and Braddock Road Metrorail stations. The route operates in both mixed traffic and a dedicated transitway; bus-only lanes operate between Potomac Avenue and East Glebe Road and between South Glebe Road and the Pentagon City Metrorail station.[xx]

Since it began operation, Metroway's ridership has grown steadily. Between September 2014 and September 2019, monthly ridership increased from about 30,000 trips to 55,000 trips, and ridership on Metroway has consistently exceeded the ridership on the route it replaced.[xxi] Between May and September 2019, when six Metrorail stations were closed for maintenance around the Metroway route, the bus's ridership rose by 60 percent, helping alleviate the impact of Metrorail service reductions. [xxii]

Figure 6: Metroway Route

Figure 7: Metroway South Glebe Station

DDOT Bus Priority Plan and Program

Nearly as many residents of the District ride Metrobus as Metrorail; however, across the city, bus speed and reliability have declined, reducing residents' access to jobs and opportunities.[xxiii] To address this, the District Department of Transportation (DDOT) is ramping up its bus priority efforts. In 2020, the agency began the development of a Bus Priority Plan, which will develop a toolbox of improvements that address bus speeds and reliability and identify a pipeline of bus priority projects.xxiv In addition to the Bus Priority Plan, DDOT has identified numerous corridors where it is pursuing bus priority projects.

H AND I STREET BUS LANES

Between June and September 2019, DDOT implemented a dedicated bus lane pilot (**Figure 8**) on H and I Streets NW between Pennsylvania Avenue and 13th Street NW to improve travel speeds and reliability for bus routes on these streets during the weekday AM and PM peak periods.[xxv] H and I Streets see up to 70 buses per hour during peak periods, and over one-fifth of bus riders in the District use these routes; however, prior to the pilot, bus travel speeds were as low as 2.8 miles per hour in some segments. Preliminary analysis showed that during the pilot period, bus speed improvements on both H and I Streets were inconsistent; however, on average, for the entire pilot period, bus speeds on both streets increased by about one mile per hour.[xxvi] Due to the observed improvements in speed and reliability, the bus lanes became permanent in November 2019. The hours of the permanent, painted bus lanes were extended from the peak periods; the permanent bus lanes operate from 7:00 a.m. and 7:00 p.m. Monday through Saturday.[xxvii]

Figure 8: H & I Street Bus Lanes in Downtown DC

DDOT 2020 TEMPORARY BUS LANES

In July 2020, DDOT installed Car Free Lanes in high-traffic corridors that will support improved efficiency in bus travel and create space for bicyclists.[xxviii] The DC Car Free Lanes, designated by red paint, will be installed during the summer of 2020 at the following locations:

- 7th Street NW between Massachusetts Avenue and Pennsylvania Avenue NW. This location is restricted to buses, bicycles, and trucks 24 hours a day, seven days a week.
- Martin Luther King Jr. Avenue, SE between W Street SE and St. Elizabeth's East Campus. This location operates as a northbound bus lane during the morning rush hour between 7:00 a.m. and 9:30 a.m. and as a southbound bus lane during the evening rush hour between 4:00 p.m. and 6:30 p.m.
- M Street SE between 10th Street and Half Street SE. This location has bus lanes operating in both directions during the morning rush hour between 7:00 a.m. and 9:30 a.m. and during the evening rush hour between 4:00 p.m. and 6:30 p.m.

BUS TRANSFORMATION PROJECT (BTP) RECOMMENDATIONS

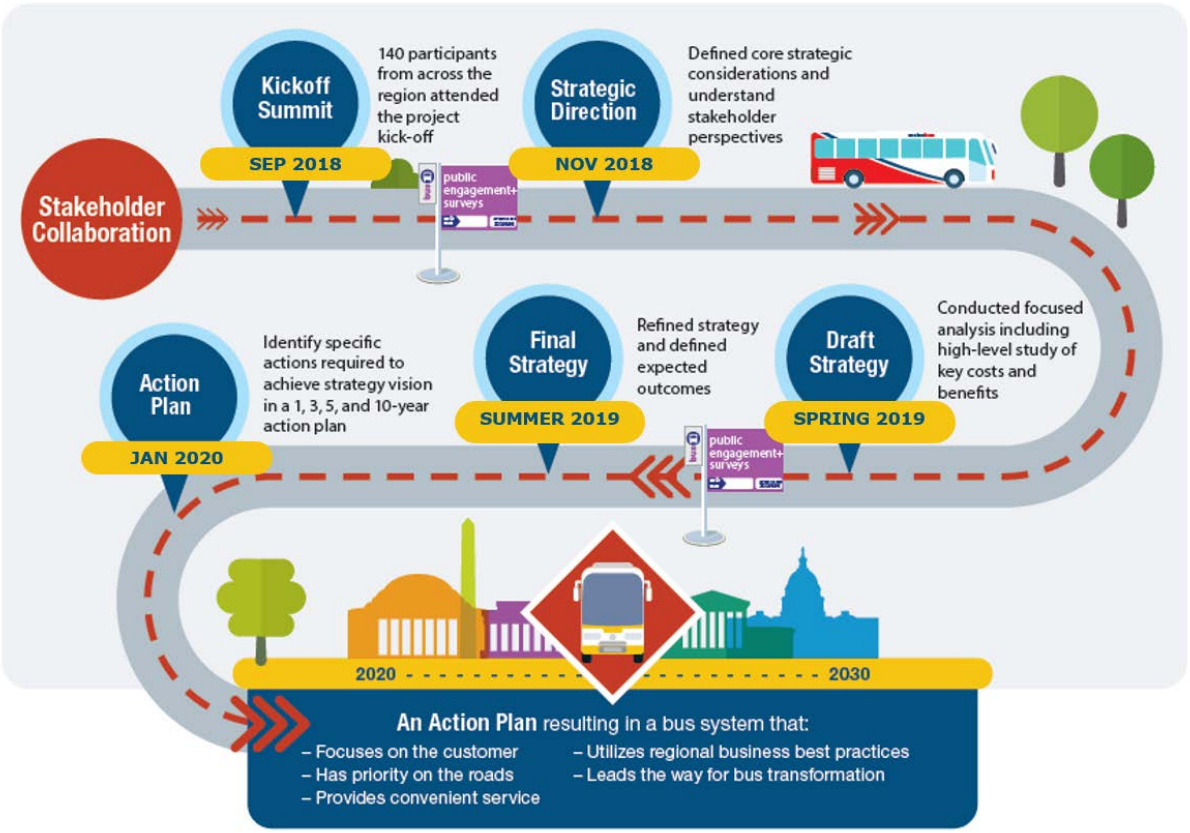
The Washington Metropolitan Area Transit Authority (WMATA)-led Bus Transformation Project was a collaborative, region-wide effort with the intent of focusing attention in the region on the importance of the NCR's bus network and the needs of its riders. Developed and shaped by a broad range of

stakeholders and the public from across the NCR, the BTP sets a vision of the bus being the mode of choice on the NCR roads by 2030, serving as the backbone of a strong and inclusive regional mobility system.

Since 2018, the Bus Transformation Project has successfully focused attention on the importance of the bus in the region. Different from a corridor study or a service plan, BTP is a plan to transform the bus in the NCR in the next decade based on extensive research and public engagement (**Figure 9**). Participation from the local agencies who provide bus service, transportation professionals, community-based organizations and agencies, workers, and the business community were critical to the development of the study. In addition to engagement with the public, four groups of stakeholders provided input and direction from throughout the project. Those groups included WMATA's leadership team and a technical team that included staff who deal directly with the provision of bus service, as well as an executive steering committee and a strategy advisory panel.[xxix]

Input from stakeholders, riders, and the public and extensive research and analysis formed the basis of the Bus Transformation Strategy and Action Plan, which focus on 'what' will change and 'how' things should change, respectively. The Strategy sets a new vision and a series of recommendations to guide the future of the bus in the region. And, the Action Plan defines critical activities and milestones over the next ten years of implementing the Strategy while connecting those activities and actors with tangible outcomes.

Figure 9: Bus Transformation Project Timeline



Public input from across all demographics and areas in the region indicated that transforming the bus system means doing the basics better - that is, providing fast, frequent, reliable, affordable bus service that feels like a unified system and is not beholden to geographic or funding boundaries. Based on that input and completed in September 2019, the Strategy lays out the desired direction and highlights 26 recommendations within four key recommendation areas:

- Provide frequent and convenient bus service
- Give buses priority on roadways
- Create an excellent customer experience
- Empower a publicly appointed task force to transform bus

The key recommendation area most closely related to this synthesis theme is to give priority to buses on roadways. This area includes a set of recommendations that details policy, capital, operating, and enforcement strategies to give priority to buses on the roadways. The plan highlights the need for transit agencies and roadway owners to work together to achieve the vision of moving people quickly and reliably, and details the following recommendations:[xxx]

- **Obtain commitments from state and local agencies** (including roadway owners) to **adopt consistent guidelines**, bolster jurisdictional capital spending, and expedite coordinated implementation of bus priority.
- Implement enforcement policies that **establish bus priority** and result in reliable and fast service.
- Establish a capital program at WMATA that **supports the accelerated implementation of bus priority projects**, including BRT.
- Support regional congestion mitigation efforts that bolster bus priority and **move more people more efficiently**.

The plan also highlights benefits and outcomes, details an implementation schedule, and define roles and responsibilities within each recommendation. For more detail on those, see *Action Plan Details*.[xxxi]

The plan indicates potential ways the region and stakeholders can commit to prioritizing buses. First, obtain a formal agreement across the region to establish regional bus priority guidelines, implement projects, and advance enforcement measures. Then, establish regional guidelines for selecting corridors to receive priority treatment considering service frequency, ridership, stop spacing, and land use characteristics. Finally, in terms of bus priority treatments, the plan lists the implementation of TSP, queue jumps, off-board fare payment, dedicated bus lanes/guideways, all-door boarding, and parking limitations, and highlights how a regional commitment to these measures drives greater impact.

Some challenges associated with preferential treatment of buses across the region include capital outlay, coordination, and political buy-in[xxxii]. These are expressed in the region's need to secure the capital expenditure required to set up bus priority treatments region; the high degree of coordination across agencies to set up pricing systems, TSP, and bus lanes; and the need to correct stakeholders' perceptions to gain political buy-in. However, case studies demonstrate many benefits as well, such as increased bus speeds and reliability, cost savings, and reduced pollution.

Several recent and underway projects in the region are aligned with the plan's recommendation to give buses priority on roadways, such as the H and I Street bus lanes, or the DC Car Free Lanes. These indicate a commitment in the region to giving priority to the bus in the NCR. The BTP defines clear action steps for each recommendation and **Table 5** lists key milestone achievements related to giving priority to buses on roadways and their timeframes.

Table 5: BTP Action Plan Milestones Under Give Buses Priority on Roadway Recommendation

Horizon Year	Timeframe	Milestone
In 2020	6 months	The region will commit to pursuing area-appropriate bus priority treatments at the policy level
In 2020	6 months	The region will develop an implementation-ready enforcement program for bus priority
In 2021	6 months	WMATA will develop a capital program for implementing bus priority in the region
In 2022	12 months	The region will have established guidelines for where and how bus priority should be implemented
In 2022	18-24 months	To appropriately enforce bus priority, the necessary equipment will have been acquired and necessary legislation will have been enacted by the appropriate state and local bodies
By 2025	Ongoing	Efforts to support and implement congestion pricing in the region will be moving forward

KEY INFORMATION FROM A LITERATURE REVIEW ON THE BENEFITS AND COSTS OF BUS PRIORITY

The topic of bus priority, its best practices, and its costs and benefits has been thoroughly studied over the past decade. The majority of literature that covers the successes and drawbacks of BRT and bus priority projects base their conclusions on case studies. According to the literature, the most common bus priority practices include transit signal priority (TSP), queue jump, bypass lanes, limited-stop, and exclusive transit lanes. For more information on each of these practices, see *TCRP Synthesis 83: Bus and Rail Preferential Treatment in Mixed Traffic*.[xxxiii]

There are several common reasons that could drive an agency to choose to implement bus priority strategies to traditional bus service. Adding priority measures to a bus system upgrades the service capacity beyond that of a traditional bus line. It creates a system that has a similar ridership capacity and speed to a rail-based service but enjoys the flexibility and cost-effectiveness of a bus system. This can make the bus a more attractive transit option for transit agencies than the comparable rail service. Additional reasons agencies have chosen to implement bus priority measures can be found in the *TCRP Synthesis 90 – Bus Rapid Transit Volume 2: Implementation Guidelines*.[xxxiv]

Bus prioritization maximizes benefits under specific conditions. An area that is most conducive to an effective bus priority corridor should have a high population density and a plethora of employment opportunities. Areas being considered for bus prioritization should have existing buses and/or a strong flow of passengers that could utilize the system.[xxxv] Having an existing bus presence smooths implementation and demonstrates an existing pool of riders.

Benefits

Bus priority systems, regardless of size and location, have several common benefits that are identified in the literature, including faster speeds, higher ridership, and an increase in transit-

oriented development. The magnitude of these benefits varies based on the level of priority buses are given within the system. For more information on these and additional benefits, please refer to the endnotes.[xxxvi]

- **Faster Speed**: With dedicated infrastructure and signal priority, prioritized buses travel at higher average speeds than traditional buses. On a congested road, the addition of a dedicated bus lane can double or triple bus travel speeds.[xxxvii] Faster average travel speeds reduce operating costs and increase the efficiency and reliability of transit service, which makes transit more appealing and increases ridership.[xxxviii]
- **Higher Ridership**: Bus priority increases bus speeds and headways, which makes taking the bus a more attractive option compared to other forms of transportation. Higher frequency systems also require more buses or larger buses, which increases capacity and allows for more passengers.
- **Development**: Bus priority infrastructure can be catalysts for redevelopment. Corridors served by prioritized buses are prime locations for business and higher-density housing because they are accessible. In Cleveland, for example, the BRT line along Euclid Avenue is credited to jumpstarting $5.8 billion in investment – $3.3 billion in new construction and $2.5 billion in building rehabilitation. Nearly all of Cleveland's new development since 2008 has occurred along or near Euclid Avenue.[xxxix]

Costs

Similar to any infrastructure or transit project, bus prioritization comes with both financial and non-financial costs. Agencies that chose to implement these projects weigh the costs and benefits and determine if the system is worth the investment. Each additional treatment comes with a marginal benefit, but also a financial cost. For example, lower-cost treatments such as bus lanes in mixed traffic are associated with the smallest time savings and ridership increase. On the other hand, as bus priority development costs increase, there is consistent growth in system ridership, but a decrease in travel times.[xl]

Table 7 presents examples of specific financial costs for different types of dedicated bus lanes. Dedicated bus lanes range from a painted lane that shares the road with mixed traffic to fully separate right-of-ways that do not allow personal vehicles. The costs presented in Table 6 were determined based on the average cost per mile of actual bus priority systems constructed in the United States over the last decade. For additional information on the infrastructure types evaluated and the methodology to determine costs, please see *TCRP Synthesis 90 – Bus Rapid Transit Volume 2: Implementation Guidelines.* In addition to monetary costs, the literature has also identified non-financial costs, such as loss of road capacity. For additional non-financial costs, please refer to the endnotes.[xli]

Table 6: Average Costs of Dedicated Bus Lane Treatments[xlii]

Dedicated Bus Infrastructure	Cost
Bus tunnel	$272 million per mile
Busway	$7.5 million per mile
Arterial median busways	$6.6 million per mile
Guided bus operations	$4.7 million per mile
Mixed traffic or curb bus lanes	$1 million per mile

Costs vary greatly even between projects with similar infrastructure types because the cost is dictated by a slew of compounding factors. These include land acquisition costs, lengths of tunnels and bridges, labor, equipment, and purchase of vehicles. It is important to reiterate that there is a direct correlation between cost and benefit – the higher the cost of the treatment, the more effective the treatment is at increasing ridership and transit efficiency. That tradeoff is an important consideration when organizations are determining what types of infrastructure to invest in.This tradeoff between a bus priority treatment's cost and that same treatment's benefit is highlighted in **Table 2** and **Table 8**.

In addition to these monetary cost estimates, the major non-monetary cost highlighted in the literature is the loss of right-of-way. As the literature points out, this is a particular issue when a mixed traffic lane is turned into a lane dedicated to buses. Beyond the political and public conflict associated with removing a travel lane, there are also logistical issues associated with downsizing the physical capacity of private vehicle travel. Some streets are narrow or already congested, and taking away a lane can exacerbate these issues. Although the long-term goal of bus prioritization is for the bus to take the place of some cars and reduce congestion, it can cause an initial increase in congestion.[xliii]

There is a tradeoff between dedicating space exclusively to bus versus bicycles versus parking versus driving. A best use for road space is dependant on the specifc circumstances of a roadway, and several factors go into determing the most appropriate use. These factors include the market, policies, and person throughput. Particilarly important in weighing this tradeoff is determing the goal of dedicating right-of-way to buses or bikes. Is it to incrase speed and reliability of buses or all vehilces on the roadway; is it to reduce greenhouse gas emissions from vehicles; or is it to improve the experience of transit users, especially transit dependant users? These factors and motivations must be considered in order to determine if the cost of creating a dedicated right-of-way for the bus is outweighted by its beneifts.

Challenges

The literature identified challenges that various agencies faced during the planning, implementation, and operation of bus priority and BRT systems, several of which are highlighted below. These are more general challenges that systems implementing bus prioritization may face regardless of local conditions. For more information on these challenges and additional challenges, please refer to the endnotes.[xliv]

- **Bus lane management**: Creating a dedicated bus lane adjacent to or within mixed traffic creates an issue of maintaining that lane's function as a bus-only lane. Despite policies or signage, drivers may still use this lane for private travel. The 2017 MWCOG Bus Lane Enforcement Study identified five components to effective bus lane management, including stakeholder coordination, enforcement, legislation, education, and monitoring.[xlv]
- **Public/Stakeholder Approval**: Any large-scale infrastructure project should have the approval of both stakeholder groups and the public the project will serve. Even though the addition of bus priority measures is meant to benefit the community, it can still be difficult to convince the public and/or the political leaders that the benefits outweigh the costs. Taking an existing lane and dedicating it to buses can be politically unpopular, and adding additional lanes or right-of-way for buses can be expensive.[xlvi] The literature emphasized the importance of engaging with the public and stakeholders early and often to gather support.[xlvii] Cleveland, Ohio, for example,

held more than 2,000 public meetings when designing and implementing its bus rapid transit system to ensure that the public was well-educated about the system and supported the work that was being done.[xlviii] The ideal number of public/stakeholder meetings varies from project to project and is dependent on many factors, including the size of the potential ridership pool and the approach to engagement. Two-thousand meetings won't always be necessary, as long as the public is engaged throughout the planning and implementation process and given time to provide input and feedback.

KEY INFORMATION FROM PEERS ON THE BENEFITS AND COSTS OF BUS PRIORITY

Much like the NCR, cities and transit agencies across the county are enhancing bus service and implementing bus priority practices to increase the reliability and efficiency of their bus transit networks. **Table 7** provides examples of some of the many bus priority efforts taking place in cities outside the NCR, highlighting the financial investment and the outcomes.

Table 7: Bus Priority Examples from Peer Cities

Location/Agency	Bus Priority Solution	Outcomes and Costs
Baltimore	BaltimoreLink Transit Priority Initiative[xlix]	With the implementation of BaltimoreLink in June 2017, MDOT MTA also implemented a 5.5-mile network of dedicated bus lanes in Downtown Baltimore on nine streets, resulting in average travel times savings of 9.3 percent per corridor and an average of less than one-minute increases to general traffic. The bus lanes have also supported safety goals; reducing bus related safety incidents by 12 percent.[l]
Chicago	Loop Link[li]	Loop Link, a network of dedicated bus lanes within Chicago's downtown, aims to improve travel flow on several key corridors. In addition to dedicated lanes, Loop Link features enhanced stations and raised platform boarding, With the aim of increasing bus speeds from three miles per hour to about four miles per hour in the peak period and six miles per hour in the off-peak period, Loop Link has seen limited success since it began operation in December 2015 due in large part to limited enforcement.[lii] Loop Link cost over $30 million to implement.[liii]
Minneapolis-St. Paul	METRO A Line[liv]	Launched in 2016, the METRO A Line is a BRT light route connecting Minneapolis and St-Paul. The high-frequency route incorporates several BRT features, including enhanced stations with off-board fare payment and rea-time trip arrival information. Ridership on the corridor grew 32% in the first year after the A Line began operation. The A Line's average speed is 19.7 miles per hour, compared to 13.4 miles per hour for local bus routes in the system.[lv] Operating costs on the A Line totaled about $7.8 million in 2018.[lvi] Implementing the A Line cost about $27 million, including $15 million to construct stations and install fare collection infrastructure and related technology.[lvii]

Location/Agency	Bus Priority Solution	Outcomes and Costs
New York City	Select Bus Service (SBS) [lviii]	MTA offers SBS on 16 routes, serving as a complement to the existing subway network on high ridership corridors. SBS routes offer features of BRT, including off-board fare payment, TSP, and consolidated stops. On average, SBS is 27 percent faster than local/limited routes.[lix] The cost of implementing and operating SBS averages about $10 million and the first four routes improve travel time by an average of 19 percent.[lx] In October 2019, NYC DOT began the 14th Street Busway pilot that bars private vehicles from making through trips on 14th Street between 6:00 a.m. and 10:00 p.m. daily. The busway was made permanent in June 2020. [lxi] As a result of the 14th Street Busway, bus travel speeds increased by 24 percent on the corridor, and ridership increased by as much as 30 percent.[lxii] Initial results also indicate that shifting local traffic to adjacent roads has a reliable impact on travel speeds.[lxiii]
Los Angeles	Metro Rapid[lxiv]	TSP on the Metro Rapid network led to an estimated 25 percent reduction in bus travel times compared to travel without TSP, an operating cost savings of $6.67 per bus per hour ($66.77 per bus per day, $24k per bus per year).[lxv] Implementing TSPs cost approximately $13,500 per signalized intersection.[lxvi]
Portland	TriMet TSP Program	TSP capabilities at over 250 intersections reduced bus travel times by 10 percent and reduced travel time variability by 19 percent. The improvements saved the agency over $13 million over eight years.[lxvii] Equipping 250 intersections with TSP costs approximately $4.5 million.[lxviii]
San Francisco	MuniForward Transit Priority Projects[lxix] and Rapid Network[lxx]	A transit lane pilot on Church Street eliminated congestion-related delays on buses on the corridor and improved reliability by 20 percent for outbound trips on the corridor. The red paint treatment of the bus lane reduced transit lane violations by 50 percent compared to non-colored transit-only lanes. The project has also not resulted in significant impacts to drivers on the corridor.[lxxi] Restriping and repainting the Church Street corridor cost about $280,000 per mile.
Seattle	RapidRide[lxxiii]	RapidRide, King County Metro's BRT light network, serves 67,000 riders every weekday, a 70 percent increase compared to the previous service. Peak hour travel is 20 percent faster than the previous service.[lxxiv] A 2013 performance evaluation of the then existing four RapidRide routes estimated that RapidRide's cost per passenger was 21 percent less than the cost per passenger of King County Metro's regular service.[lxxv] TSP, signal timing, and ITS infrastructure investments cost $1.76 million to $2.78 million for four lines, contributing to travel time reductions and improvements in on-time performance. Implementing real-time infrastructure cost $400,000 to $1 million per Route for 6 RapidRide routes, and investments in off-board fare readers cost between $95,000 to $300,000 on six RapidRide routes.[lxxvi]
Toronto	Viva BRT[lxxvii]	Viva, express bus service, opened in York, a suburb of Toronto, in 2005, with BRT features, including frequent service, limited stops, and off-board fare collection. York Region Transit began construction of dedicated rapidways in 2011, which will eventually result in over 34 kilometers of dedicated road space.[lxxviii] Between 2005 and 2013, York transit ridership increased by 26 percent. Key to Viva's success is it's marking campaign, which focuses on selling a lifestyle. The full network of transitways costs approximately 1.7 billion Canadian dollars ($1.2 billion USD).[lxxx]

SUMMARY OF EXPECTED BENEFITS AND COSTS OF PRIORITY TYPE

Implementing bus priority in the NCR requires significant investment, but as highlighted by the examples, adding bus priority treatments can have major positive impacts on bus reliability and efficiency, thereby improving the region's residents' access to jobs and opportunities. Not only do bus

priority treatments improve the experience for existing bus riders, as Metroway, RapidRide, and Viva all illustrate, bus priority treatments make transit more attractive and help attract new transit riders. The specific benefits of each treatment vary based on the conditions in which the treatment is implemented; however, the examples clearly show that bus priority treatments work, especially when implemented in tandem with one another. That is, a dedicated lane implemented with all-door boarding and consolidated bus stops will have more positive benefits than a dedicated bus lane on its own. Dedicated busways, coupled with transit signal priority, have the potential to improve peak hour travel speeds by up to 30 percent.

Table 8 highlights a sample of bus priority improvements, the cost and degree of difficulty to implement, and cost savings/performance improvements.[lxxxi] While lower-cost improvements provide some benefit and can be easier to implement, higher levels of investment can result in high-cost savings and/or performance improvements. Cost savings are derived from increasing operational efficiencies as well as by reducing fuel costs, which comes with reducing the amount of congestion buses operate in as well as idle time at stops. Note that the degree of difficulty in the table highlights the degree of difficulty in implementing a bus priority improvement; however, this metric is variable based on site-specific considerations. Even those improvements that are a low degree of difficulty can have a time frame of at least a year and require significant planning and coordination efforts. Implementing TSP at some intersections on a corridor, for example, still requires a robust planning and testing process before TSP can go into operation. Alternatively, designating an on-road dedicated bus lane can be as simple as painting the roadway and adding new signage. As improvements are coupled together to provide a greater to speed and reliability benefits, the level of effort required for implementation grows.

Table 8: Bus Priority Costs and Impacts

Improvement	Improvement Description	Cost to Implement	Degree of Difficulty to Implement	Cost Savings/ Performance Improvements	Level of Anticipated Improvement
TSP	Installed at some intersections, operated on a conditional basis	$0.3M to $9.0M per mile	Low to Moderate*	8% in travel time savings; $0.2M to $1.6M cost savings annually	Low
Dedicated Lane	Dedicated lane on existing road	$0.2M to $1M per mile	Low	$0.25M in savings per year; 10-14% travel time savings, up to 27% increase in reliability	Moderate
TSP and Queue Jumps	Dense network of TSP and queue jumps at some intersections	$0.3M to $20M per mile	Low to Moderate*	1-10% in travel time savings; $0.3M to $1.7M cost savings annually	Low
TSP, Queue Jumps, Dedicated Lanes	Dense network of TSP, queue jumps at all intersections, dedicated lanes on the full route	$5.0M to $50M per mile	Moderate to High	18-54% in travel time savings; $0.55M to $1.95M in cost savings annually	Moderate to High

  TSP and Dedicated Guideway	Dense network of TSP, exclusive bus right-of-way	$30M to $80M per mile	High	18-66% in travel time savings; $0.55M to $1.8M cost savings annually	High

*TSP implementation can be costly and time consuming due to variations in technology and hardware

NEAR TERM AND FUTURE PROJECTS IN THE NCR

Beginning with TIGER, which awarded $58.8 million to the NCR in federal grant funding in 2010, bus priority projects have continued to grow in prominence in the region. The NCR's commitment to improving bus travel was cemented by the Bus Transformation Project. The resulting Bus Priority Strategy provides recommendations for transforming the NCR's bus system into a fast, frequent, reliable, affordable, and unified service. The Action Plan charts out an approach for implementing those recommendations.

A key recommendation to come out of the Bus Priority Project was to give buses priority on roadways to move people quickly and reliably. Numerous projects are under construction or in early planning phases that directly address this recommendation, helping to push the region towards the Bus Transformation Project's vision. These bus priority projects are not yet operational so no concrete conclusions can be drawn regarding their impact on bus reliability and efficiency. However, the projects highlight what the future NCR's bus network will look like. These projects will ultimately help create a convenient and reliable network for NCR residents to access jobs and opportunities.

Near term bus priority projects

The following projects are currently under construction and will begin operation within the next couple of years.

14TH STREET BUS LANE DEMONSTRATION PROJECT

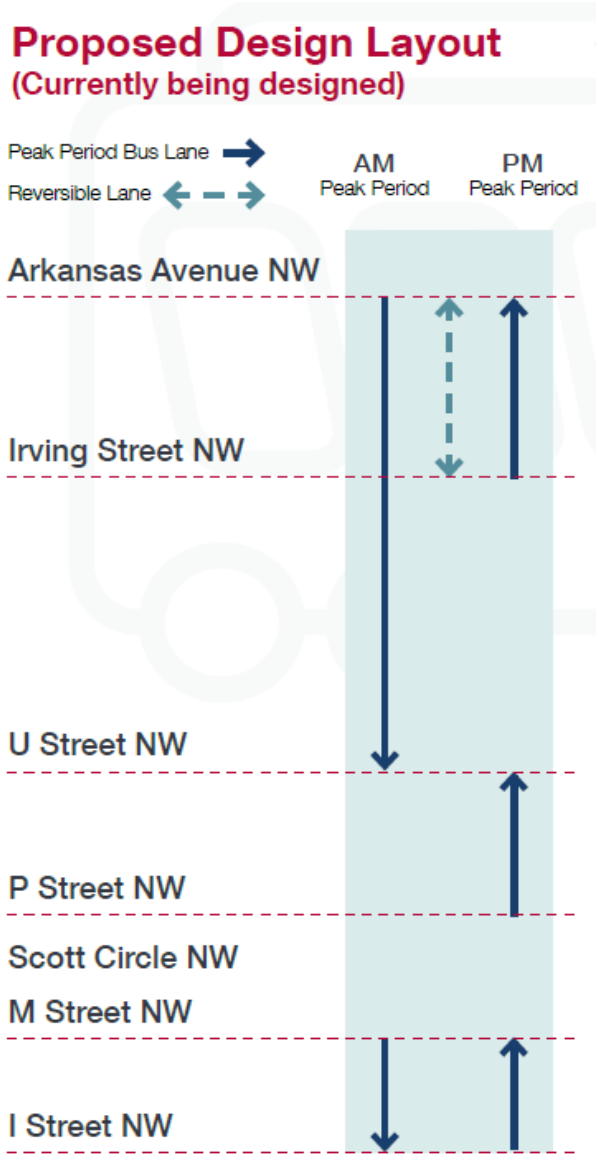
The 14th Street Traffic Decongestion and Bus Improvement project on 14th Street between Euclid and Newton Streets NW includes several bus priority treatments, including dedicated bike and bus lanes, bus stop consolidation, and parking limitations. The project will improve the performance of the DC Circulator and Metrobus Routes 52, 56, and 59, which combined carry over 15,500 travelers daily. The demonstration project began construction in Summer 2020 and will be implemented for one year.[lxxxii] **Figure 10** presents a proposed cross-section of an intersection on the corridor. [lxxxiii]

Figure 10: Proposed Cross Section on 14th Street NW

16TH STREET BUS PRIORITY STUDY

The 16th Street Bus Priority Study analyzed potential service, physical, and operational improvements to 16th Street NW to improve bus reliability and efficiency. Sixteenth Street NW is one of the busiest streets in WAMTA's network, serving over 20,000 passengers per weekday. By 2016, the S9 MetroExrtra limited-stop service, signal timing optimization, and transit signal priority were all operating on the corridor. However, as a result of the study, additional bus priority improvements will be implemented on 16th Street NW, including bus queue jumps, all-door boarding, off-board fare payment, bus stop consolidation, dedicated bus lanes, and parking limitations. Construction on the 16th Street corridor is expected to begin in Fall 2020. These improvements are expected to reduce travel times in both directions by two to five minutes compared to the existing service.[lxxxiv] **Figure 11** shows a sample of improvements planned for the corridor. [lxxxv]

Figure 11: 16th Street Bus Lanes Proposed Layout



MONTGOMERY COUNTY BUS RAPID TRANSIT

In 2013 Montgomery County adopted the *Countywide Transit Corridors Functional Master Plan*, which recommends 11 BRT corridors in the county.[lxxxvi] The first route from this plan, operating on US 29 as US 29 FLASH, recently completed construction and began operation on October 14, 2020.[lxxxvii] The route operates on bus-on-shoulder lanes between Burtonsville and Tech Road and transitions to mixed traffic between Tech Road and the Silver Spring Transit Center. The corridor also has TSP installed at 15 intersections to improve bus operations. US 29 FLASH is expected to reduce travel time by 22 to 35 percent on the corridor compared to existing local bus service. The BRT route is also expected to result in over $250 million of economic net benefit; White Oak Science Gateway, among other development projects, will benefit from the presence of high-quality transit.[lxxxviii]

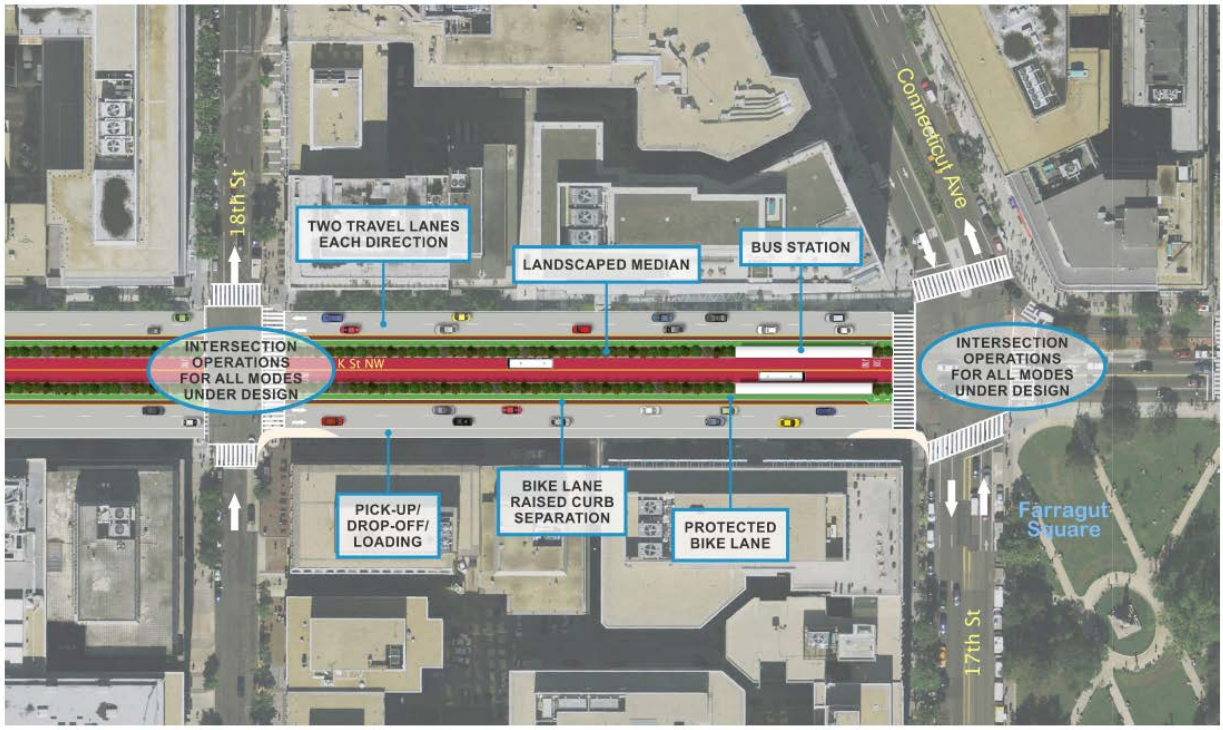
Future bus priority projects in the NCR

In addition to the projects currently under construction, several additional bus priority projects in the NCR are in the early stages of project development. These projects, described in the following, will not be operational for several years.

K STREET TRANSITWAY FUTURE PROJECT

DDOT is planning the K Street Transitway, which will transform K Street, one of the District's most heavily traveled downtown corridors. The transitway will consist of a two-way dedicated busway, separated by medians, running in the center of K Street between 12th Street NW and 21st Street NW. This busway is designed to carry at least 13 bus routes with 55 buses per hour per direction during peak periods. The plan also calls for general purpose travel lanes, an off-peak parking lane in each direction, and a dedicated cycle track in each direction. A sample block is illustrated in **Figure 12**. Construction is expected to begin in 2022, with the Transitway opening in 2024. Once complete, travel times on the transitway are expected to improve by 30 percent compared to existing conditions.[lxxxix]

Figure 12: K Street Transitway Sample Block Layout



PENNSYLVANIA AVENUE SOUTHEAST CORRIDOR

DDOT is currently studying the Pennsylvania Avenue corridor from the west side of the Sousa Bridge to 2nd Street SE, near the US Capitol. The study aims to identify opportunities for improving safety and mobility on the corridor for cyclists, pedestrians, and vehicular travel. The 30S Metrobus line also operates on the avenue, which carries over 11,000 passengers daily. Still underway, the study will identify opportunities for bus priority improvements, such as bus lanes.[xc]

EMBARK RICHMOND HIGHWAY BRT

Fairfax County adopted the Embark Richmond Highway Study in 2018, which proposes a BRT line on Route 1 between Interstate 495 and Woodbridge.[xci] The planned BRT, which is not expected to begin construction for several years, will operate on an exclusive transitway with off-board fare payment

and level boarding, among other features of BRT. A study by the Virginia Department of Rail and Public Transportation estimates travel time savings of up to nine minutes.[xcii]

ENVISION ROUTE 7

The Envision Route 7 BRT project is a planned BRT service that connects the Mark Center in Alexandria to Tysons through Bailey's Crossroads, Seven Corners, and Falls Church. The project is part of a network of BRT services being planned, designed, and implemented to better link Northern Virginia that includes the Metroway BRT in the City of Alexandria and Arlington County, Transitways in the City of Alexandria, and the Embark Richmond Highway BRT in Fairfax County. In the current planning phase, the focus is on updating the initial running way assumptions and identifying the specific station locations so that the needed rights-of-way (ROW) can be identified and a cost estimate may be determined. Future phases will focus on traffic impacts and benefits, and environmental and detailed design efforts.[xciii]

ALEXANDRIA TRANSITWAY CORRIDORS

The City of Alexandria Transitway Corridors Plans build on the 2008 City Council adopted Transportation Master Plan recommendation for providing enhanced transit service in the North-South, Duke Street, and Van Dorn/Beauregard corridors. North-South Corridor is complete and served by Metroway service. Duke Street Corridor (Corridor B) would connect Alexandria to Fairfax County to the west. It has the potential to serve the Eisenhower East area, Landmark Mall, Foxchase, Alexandria Commons, the King Street Metrorail station, and portions of Old Town. Van Dorn/ Beauregard Corridor (Corridor C) would run along Beauregard Street and Van Dorn Street and has the potential to tie to Columbia Pike, Fairfax County, and the Pentagon area, connecting to the Van Dorn Street Metrorail station on the south.[xciv]

---

[i] BaltimoreLink Transit Priority Toolkit, Maryland Department of Transportation, June 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/Transit%20Priority%20Initiative/BaltimoreLink_Transit_Priority_Toolkit.pdf

[ii] BaltimoreLink Transit Priority Toolkit, Maryland Department of Transportation, June 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/Transit%20Priority%20Initiative/BaltimoreLink_Transit_Priority_Toolkit.pdf

[iii] Kittelson and Associates, Inc.

[iv]BaltimoreLink Transit Priority Toolkit, Maryland Department of Transportation, June 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/Transit%20Priority%20Initiative/BaltimoreLink_Transit_Priority_Toolkit.pdf

[v] BTP White Paper 2

[vi] MWCOG, https://www.mwcog.org/transportation/tiger/

[vii] The City of Alexandria, Virginia; the District of Columbia Department of Transportation (DDOT); the Maryland Department of Transportation (MDOT); the Potomac and Rappahannock Transportation Commission (PRTC); and the Washington Metropolitan Area Transit Authority (WMATA).

[viii] *BTP Strategy and Recommendations*, Bus Transformation Project https://bustransformationproject.com/wp-content/uploads/2019/09/Bus_Transformation_Strategy_and_Recommendations_2019-09-05.pdf

[ix] Washington Area Bus Transformation Project, https://bustransformationproject.com/; King County Metro, *Transit Speed and Reliability Guidelines and Strategies,* https://kingcounty.gov/~/media/depts/transportation/metro/about/planning/speed-reliability-toolbox.pdf

[x] BaltimoreLink Transit Priority Toolkit, Maryland Department of Transportation, June 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/Transit%20Priority%20Initiative/BaltimoreLink_Transit_Priority_Toolkit.pdf

[xi] BaltimoreLink Transit Priority Toolkit, Maryland Department of Transportation, June 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/Transit%20Priority%20Initiative/BaltimoreLink_Transit_Priority_Toolkit.pdf

[xii] Kittelson and Associates, Inc.

[xiii]BaltimoreLink Transit Priority Toolkit, Maryland Department of Transportation, June 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/Transit%20Priority%20Initiative/BaltimoreLink_Transit_Priority_Toolkit.pdf

[xiv] BTP White Paper 2

[xv] MWCOG, https://www.mwcog.org/transportation/tiger/

[xvi] The City of Alexandria, Virginia; the District of Columbia Department of Transportation (DDOT); the Maryland Department of Transportation (MDOT); the Potomac and Rappahannock Transportation Commission (PRTC); and the Washington Metropolitan Area Transit Authority (WMATA).

[xvii] Kittelson & Associates, Inc., http://www.kittelson.com/

[xviii] WMATA Office of Business Transformation, June 30, 2020
[xix] "Transit Vehicle Signal Priority & Emergency Vehicle Preemption," City of Alexandria Traffic Engineering Division, https://www.alexandriava.gov/tes/info/default-116073.html?id=116073
[xx] Metroway, http://metrowayva.com/
[xxi] "Crystal City-Potomac Yard Transitway Project," City of Alexandria, May 30, 2019, https://www.alexandriava.gov/tes/info/default.aspx?id=58644, "Crystal City Potomac Yard Transitway," Arlington Virginia, https://projects.arlingtonva.us/projects/crystal-city-potomac-yard-transitway/, Transitway Extension to Pentagon City, Arlington, Virginia, https://projects.arlingtonva.us/projects/transitway-extension-to-pentagon-city/
[xxii] Ethan Goffman, "Northern Virginia's Metroway Corridor Shows How Buses and Trains Can Complement Each Other," Mobility Lab, September 30, 2019, https://mobilitylab.org/2019/09/30/northern-virginias-metroway-corridor-shows-how-buses-and-trains-can-complement-each-other/.
[xxiii] Bus Priority Two Pager
[xxiv] "DDOT Bus Priority", District Department of Transportation, https://ddot.dc.gov/page/bus-priority#:~:text=DDOT%20is%20kicking%20off%20a,at%20buspriority%40dc.gov.
[xxv] I "Eye" Street bus lane," BeyondDC, Flikr, https://www.flickr.com/photos/beyonddc/47998185843/in/photolist-2g8rfqk-2g8rhbp-FXkMeh-Gei6oW-ocTLTx-GgBjnH-FXkJBo-2h1MmbM-7wMez7-XDNmZM-2g83Z83-9qsatt-hod5MA-DrbpJn-2g8runB-2g8rhhS-2g8rfhQ-XDNmhK-X3KDhs-2g8rhQe-X3KFuo-2g8rgbC-Wqj95D-2g8rfvL-2g8rgbJ-XTTjTf-2g8rfYo-2g8rsG2-2g8rgBy-XDNo9v-XDNnBP-bykMBo-2g8rggD-2g8rfKi-2g8rh18-2g8rgo6-ReGr3A-Ya12zM-2g93NRT-JecFBm-WTfhrW-XxYa3b-XxY7x1-JecJd3-Hs6VoT-HXxUwU-9wMKWF-2g8rfnp-ndGgn7-JecJb9
[xxvi] Christina Moscardi, "How well do DC's red-painted bus lanes work?", February 20, 2020, http://www.christianmoscardi.com/blog/2020/02/20/dc-bus-lanes.html
[xxvii] "H & I Street NW Bus Lane," District Department of Transportation, https://ddot.dc.gov/page/h-i-streets-nw-bus-lane
[xxviii] "Car Free Lanes" District Department of Transportation, https://ddot.dc.gov/node/1484591
[xxix] *Project Committees and Advisors*, https://bustransformationproject.com/about/#description
[xxx] *BTP Strategy and Recommendations*, Bus Transformation Project https://bustransformationproject.com/wp-content/uploads/2019/09/Bus_Transformation_Strategy_and_Recommendations_2019-09-05.pdf
[xxxi] Action Plan Details, https://bustransformationproject.com/wp-content/uploads/2019/12/Action-Plan-2019-12-06-SECURE.pdf
[xxxii] BTP White Paper #2: Strategic Considerations, https://bustransformationproject.com/wp-content/uploads/2019/01/White-Paper-2_FINAL.pdf
[xxxiii] *TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic*
[xxxiv] *TCRP Report 90 Bus Rapid Transit Volume 2: Implementation Guidelines*, https://nacto.org/docs/usdg/tcrp_rpt_90_implementation_guidelines_volume_2_levinson.pdf
[xxxv] *TCRP Report 90 Bus Rapid Transit Volume 2: Implementation Guidelines,* https://nacto.org/docs/usdg/tcrp_rpt_90_implementation_guidelines_volume_2_levinson.pdf
[xxxvi] *TCRP Report 90 Bus Rapid Transit Volume 2: Implementation Guidelines, TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic, When are bus lanes warranted? Considering economic efficiency, social equity, and strategic planning goals*
[xxxvii] *When are bus lanes warranted? Considering economic efficiency, social equity, and strategic planning goals,* Victoria Transportation Policy Institute, https://www.vtpi.org/blw.pdf
[xxxviii] TCRP Report 118 Bus Rapid Transit Practitioners Guide, https://nacto.org/wp-content/uploads/2015/04/tcrp118brt_practitioners_kittleson.pdf
[xxxix] *A National Synthesis of Transit in Complete Streets*, https://www.fdot.gov/docs/default-source/transit/documents/FDOTCO_ANationalSynthesisofTransitinCompleteStreets_FinalReport_20180508.pdf
[xl] *TCRP Report 118 Bus Rapid Transit Practitioners Guide*, https://nacto.org/wp-content/uploads/2015/04/tcrp118brt_practitioners_kittleson.pdf
[xli] *Characteristics of Bus Rapid Transit for Decision-Making,* Federal Transit Administration, https://www.transit.dot.gov/sites/fta.dot.gov/files/CBRT_2009_Update.pdf
[xlii] *TCRP Report 90 Bus Rapid Transit Volume 2: Implementation Guidelines,* https://nacto.org/docs/usdg/tcrp_rpt_90_implementation_guidelines_volume_2_levinson.pdf
[xliii] *Characteristics of Bus Rapid Transit for Decision-Making,* Federal Transit Administration, https://www.transit.dot.gov/sites/fta.dot.gov/files/CBRT_2009_Update.pdf
[xliv] *Characteristics of Bus Rapid Transit for Decision-Making*, Federal Transit Administration, https://www.transit.dot.gov/sites/fta.dot.gov/files/CBRT_2009_Update.pdf
[xlv] *Bus Lane Enforcement Study,* Metropolitan Washington Council of Governments, https://www.mwcog.org/assets/1/28/10062017_-_Item_12_-_DO_NOT_PRINT_-_Bus_Lane_Enforcement_Study_Final_Report.pdf
[xlvi] *Characteristics of Bus Rapid Transit for Decision-Making*, Federal Transit Administration, https://www.transit.dot.gov/sites/fta.dot.gov/files/CBRT_2009_Update.pdf
[xlvii] *TCRP Report 90 Bus Rapid Transit Volume 2: Implementation Guidelines,* https://nacto.org/docs/usdg/tcrp_rpt_90_implementation_guidelines_volume_2_levinson.pdf
[xlviii] *A National Synthesis of Transit in Complete Streets*, https://www.fdot.gov/docs/default-source/transit/documents/FDOTCO_ANationalSynthesisofTransitinCompleteStreets_FinalReport_20180508.pdf
[xlix] Transit Priority Initiative, Maryland Department of Transportation Maryland Transit Authority, https://www.mta.maryland.gov/transit-priority-initiative

[l] *Dedicated Bus Lanes Before and After Study,* MDOT MTA, February 2019, https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/System%20Information/DBL_Report_022019.pdf
[li] Loop Link, Chicago Transit Authority, https://www.transitchicago.com/looplink/
[lii] Blair Kamin, "Chicago's Loop Link not exactly rapid, but a step in the right direction," *Chicago Tribune*, January 9, 2016. https://www.chicagotribune.com/columns/ct-loop-link-review-kamin-met-0110-20160108-column.html
[liii] Blair Kamin, "Chicago's Loop Link not exactly rapid, but a step in the right direction," *Chicago Tribune*, January 9, 2016. https://www.chicagotribune.com/columns/ct-loop-link-review-kamin-met-0110-20160108-column.html
[liv] "A Line," Metro Transit, https://www.metrotransit.org/a-line
[lv] "Metro Transit A Line 2017 Snap Shot," Metro Transit, https://www.metrotransit.org/Data/Sites/1/media/abrt/aline/11-002-01-18_aline_factsheet.pdf
[lvi] *Metropolitan Area Transit Finance Report,* Metropolitan Council, October 2018, https://metrocouncil.org/Transportation/Publications-And-Resources/Finance/Metropolitan-Area-Transit-Finance-Report,-2018.aspx
[lvii] "A Line Project FAQs," Metro Transit, https://www.metrotransit.org/a-line-project-faqs#:~:text=The%20total%20cost%20of%20the,technology%20and%20fare%20collection%20elements&text=%244%20million%20to%20design%20the%20stations%2C%20roadway%20improvements%20and%20technology
[lviii] "About Select Bus Service." New York City Department of Transportation. https://www1.nyc.gov/html/brt/html/about/about.shtml.
[lix] *Better Bus Action Plan*. New York City Department of Transportation. 2019. https://www1.nyc.gov/html/brt/downloads/pdf/better-buses-action-plan-2019.pd
[lx] *Select Bus Service,* New York City Department of Transportation and New York City Transit, http://www.nyc.gov/html/brt/downloads/pdf/brt-routes-fullreport.pdf.
[lxi] "14th Street Busway," NYC DOT, https://www1.nyc.gov/html/brt/html/routes/14th-street.shtml
[lxii] "14th Street Busway," NYC DOT, https://www1.nyc.gov/html/brt/html/routes/14th-street.shtml
[lxiii] "Banning Cars on 14th Street, No Problem," Inrix, https://inrix.com/blog/2019/10/nyc-busway/
[lxiv] "Bus Rapid Transit Studies," LA Metro, https://www.metro.net/projects/bus-rapid-transit-studies/
[lxv] *White Paper #2: Strategic Considerations*, Bus Transformation Project, 2019, https://bustransformationproject.com/wp-content/uploads/2019/01/White-Paper-2_FINAL.pdf
[lxvi] *White Paper #2: Strategic Considerations*, Bus Transformation Project, 2019, https://bustransformationproject.com/wp-content/uploads/2019/01/White-Paper-2_FINAL.pdf
[lxvii] *White Paper #2: Strategic Considerations*, Bus Transformation Project, 2019, https://bustransformationproject.com/wp-content/uploads/2019/01/White-Paper-2_FINAL.pdf
[lxviii] *White Paper #2: Strategic Considerations*, Bus Transformation Project, 2019, https://bustransformationproject.com/wp-content/uploads/2019/01/White-Paper-2_FINAL.pdf
[lxix] "Muni Froward Transit Priority Projects," San Francisco Municipal Transit Agency, https://www.sfmta.com/projects/muni-forward-transit-priority-projects
[lxx] "Muni Forward Rapid Network" San Francisco Municipal Transit Agency, https://www.sfmta.com/projects/muni-forward-rapid-network
[lxxi] *Implementation Workbook*, Muni Forward, San Francisco Municipal Transportation Agency, 2015, https://www.sfmta.com/sites/default/files/reports-and-documents/2018/04/muni_forward_implementation_workbook_v16.3_web.pdf
[lxxii] *Church Street Transit Lanes Final Report*, SFMTA, https://www.sfmta.com/sites/default/files/agendaitems/2015/6-2-15%20Item%2012%20%20Church%20St.%20Rapid%20Pilot%20-%20Final%20Report_1.pdf
[lxxiii] RapidRide, King County Metro, https://kingcounty.gov/depts/transportation/metro/travel-options/bus/rapidride.aspx.
[lxxiv] RapidRide Expansion, King County Metro, https://kingcounty.gov/depts/transportation/metro/programs-projects/fares-routes-and-service/rapidride-expansion.aspx; *Transit Master Plan*, City of Seattle Department of Transportation, 2016, https://www.seattle.gov/Documents/Departments/SDOT/TransitProgram/TMPSupplmtALL2-16FINAL.pdf
[lxxv] King County Metro RapidRide Performance Evaluation Report, King County Metro, http://metro.kingcounty.gov/am/reports/2014/rapidride-performance-evaluation-report-2014.pdf
[lxxvi] King County Metro RapidRide Performance Evaluation Report, King County Metro, http://metro.kingcounty.gov/am/reports/2014/rapidride-performance-evaluation-report-2014.pdf
[lxxvii] Viva, York Region Transit, https://www.yrt.ca/en/our-services/viva.aspx
[lxxviii] [lxxviii] YRT/Viva Bus Rapid Transit, Metrolinx, http://www.metrolinx.com/en/greaterregion/projects/york-viva-bus-rapid-transit.aspx
[lxxix] Jesse Thomas, "Suburban Toronto's Viva offers lessons for Montgomery BRT," *Greater Greater Washington*, August 27, 2013, https://ggwash.org/view/32171/suburban-torontos-viva-offers-lessons-for-montgomery-brt
[lxxx] YRT/Viva Bus Rapid Transit, Metrolinx, http://www.metrolinx.com/en/greaterregion/projects/york-viva-bus-rapid-transit.aspx
[lxxxi] Washington Area Bus Transformation Project, https://bustransformationproject.com/; King County Metro, *Transit Speed and Reliability Guidelines and Strategies,* https://kingcounty.gov/~/media/depts/transportation/metro/about/planning/speed-reliability-toolbox.pdf
[lxxxii] "14th Street NW Bus and Bike Lanes Demonstration Project," District Department of Transportation, https://ddot.dc.gov/page/14th-street-nw-bus-and-bike-lanes-demonstration-project
[lxxxiii] "14th Street NW – Girard to Harvard Street – Looking North," 14th Street Columbia Heights Traffic Decongestion and Bus Improvements, Cross-Section of Proposed Imporvements, District Department of Transportation, https://drive.google.com/file/d/1agx5sqbLRZxcnCnf87xdd3LnI4pi0cEY/view.
[lxxxiv] 16th Street NW Bus Lanes Project, https://www.16thstreetnwbus.com/
[lxxxv] K Street NW Bus Lane Proposed Design, District Department of Transportaiton, https://www.16thstreetnwbus.com/wp-content/uploads/2018/07/16th-St-Online-Public-Meeting-072718.pdf

[lxxxvi] Montgomery Planning, *Countywide Transit Corridors Functional Faster Plan*, Montgomery County, MD, https://montgomeryplanning.org/planning/transportation/transit-planning/countywide-transit-corridors-functional-master-plan/
[lxxxvii] FLASH, https://www.ridetheflash.com/us29/.
[lxxxviii] MCDOT US 29 BRT Project Summary, https://www.ridetheflash.com/wp-content/uploads/2018/04/US_29_March2018_Open_Houses_Boards.pdf
[lxxxix] K Street Transitway, https://ddot.dc.gov/node/534022
[xc] Pennsylvania Avenue Southeast Corridor Study, https://w"ww.pennavese.com/
[xci] "Embark Richmond Highway – Plan Amendment 2015-IV-MV1; Adopted Amendment No. 2017-10 & No. 2017 P-02," Fairfax County, VA, https://www.fairfaxcounty.gov/planning-development/embark-richmond-highway
[xcii] "Richmond Highway Bus Rapid Transit (BRT)", Fairfax County, Virginia, https://www.fairfaxcounty.gov/transportation/richmond-hwy-brt. *Route 1 Multimodal Alternatives Analysis*. Virginia Department of Rail and Public Transportation and Virginia Department of Transportation, http://www.drpt.virginia.gov/media/1591/route-1-final-report-with-appendices-february-2015.pdf.
[xciii] Envision Route 7, http://www.novatransit.org/programs/route7/
[xciv] City of Alexandria Transitway Corridor Feasibility Study https://www.alexandriava.gov/HighCapacityTransit