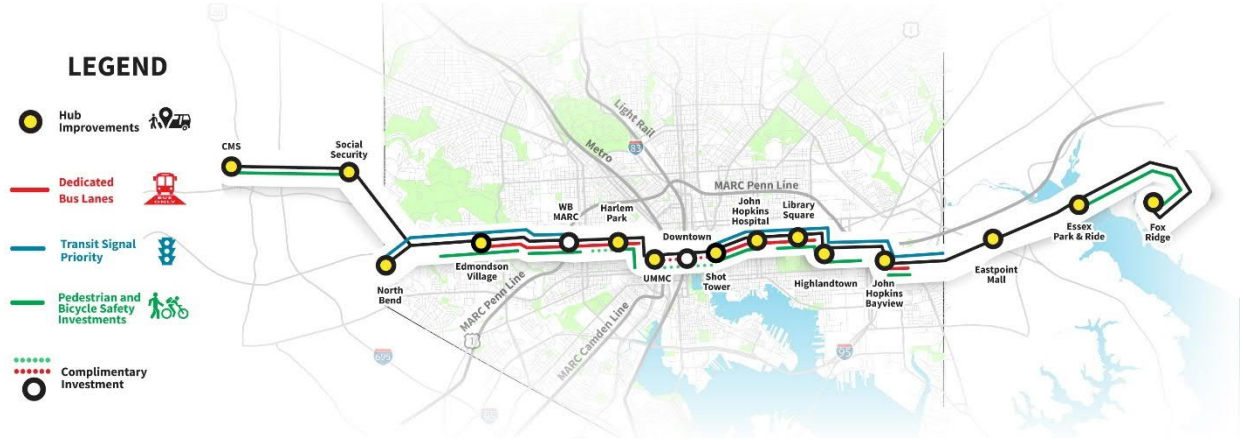
APPENDIX 1

EAST-WEST PRIORITY CORRIDOR

BENEFIT-COST ANALYSIS SUPPLEMENTARY DOCUMENTATION



FY2021 RAISE DISCRETIONARY GRANT PROGRAM

PREPARED FOR: MARYLAND DEPARTMENT OF TRANSPORTATION MARYLAND TRANSIT ADMINISTRATION (MDOT MTA) & BALTIMORE CITY DEPARTMENT OF TRANSPORTATION (BCDOT)

JULY 12, 2021

EXECUTIVE SUMMARY

A benefit-cost analysis (BCA) was conducted for the ***East-West Priority Corridor Project*** ("the Project") for submission to the U.S. Department of Transportation (U.S. DOT) as a requirement of a discretionary grant application for the Rebuilding American Infrastructure with Sustainability and Equity (RAISE) 2021 grant program. The analysis was conducted in accordance with the benefit-cost methodology outlined by U.S. DOT in the Benefit-Cost Analysis Guidance for Discretionary Grant Programs, released in February 2021. The period of analysis corresponds to 25 years and includes 5 years of construction and 20 years of benefits after operations begin in 2027.

The Project consists of a multi-modal transportation enhancement project that will add transit, pedestrian, and bicycle infrastructure improvements along a 20-mile opportunity corridor in Baltimore, Maryland. These improvements will facilitate faster and more reliable transit trips, strengthen multi-modal connections, and address existing pedestrian safety issues in order to enhance access and mobility to essential services, jobs, and schools in this priority corridor in Baltimore. The Project applies strategies and design guidance from both the MDOT MTA Transit Priority Toolkit and the Baltimore City Complete Streets Manual to directly address existing challenges on a 20-mile corridor that crosses Baltimore City and connects into Baltimore County carrying two of the region's highest-ridership bus routes. As over 17,000 households within a quarter mile of the East-West Priority Corridor do not have a car, many residents in the Project area depend on transit to access jobs, education, health care, and other essential services and amenities.

The Project elements include:

- Dedicated bus lanes on 10 miles of the corridor;
- Transit signal priority and signal timing improvements;
- Bus stop enhancements, including shelters, benches and safety improvements;
- Wayfinding upgrades and real-time information;
- ADA improvements to sidewalks and bus stops;
- Pedestrian safety improvements, including curb extensions and pedestrian-scale lighting;
- A buffered, on-street bicycle lane connecting downtown Baltimore to a major transit hub in the corridor; and
- Electric vehicle charging stations.

MDOT MTA and BCDOT selected this corridor for significant transit, pedestrian, and bicycle infrastructure investment because of its potential to advance equity in the Baltimore region and expand transit access to over 180,000 jobs. The Project would shorten transit commute times and transit reliability for residents of some of the nation's highest-poverty communities and strengthen direct connections between these communities and employment centers, social services, education, and healthcare.

COSTS

The capital cost for the Project is expected to be $50 million in year-of-expenditure dollars, or $46.3 million in undiscounted 2019 dollars when escalation costs are removed. At a 7 percent real discount rate, these costs are $33.4 million in present value. Table ES-1 shows how these costs are allocated across time and major expense category.

Table ES-1: Project Costs by Category and Year, in Undiscounted Millions of 2019 Dollars

Cost Category	2022	2023	2024	2025	2026	Total
Bus Stops	-	-	-	$3.30	$3.30	$6.59
TSP	-	-	-	$0.28	$0.28	$0.57
Dedicated Bus Lanes	-	-	-	$6.33	$6.33	$12.66
Bike Facilities / Slow Streets	-	-	-	$2.31	$2.31	$4.62
Construction Start-Up Costs	-	-	-	$5.28	-	$5.28
Design Costs	-	$1.78	$1.78	-	-	$3.57
Soft Costs	$2.61	$2.61	$2.61	$2.61	$2.61	$13.05
Total	**$2.61**	**$4.39**	**$4.39**	**$20.11**	**$14.83**	**$46.34**
Total, Discounted 7%	**$2.28**	**$3.59**	**$3.35**	**$14.34**	**$9.88**	**$33.44**

Source: Maryland Department of Transportation Maryland Transit Administration (MDOT MTA), WSP

In addition to the upfront capital cost, the repainting the dedicated bus lanes is expected to cost $2 million every 3 years. Over the 20-year analysis period, these costs accumulate to $12 million in undiscounted 2019 dollars, or $3.9 million when discounted at 7 percent. These costs are included as a negative benefit in the numerator of the benefit-cost ratio calculation, per U.S. DOT guidance.

BENEFITS

In 2019 dollars, the Project is expected to generate $77.7 million in discounted benefits over the analysis period using a 7 percent discount rate. The Project generates the benefits by improving the travel time for transit users, reducing the incidents of collisions between vehicles and pedestrians/bicyclists, generating agency cost savings by reducing demand for paratransit services, and reducing emissions and operating costs related to vehicles as a percentage of users shift to transit service to complete their trips. These improvements throughout the project area leads to an overall project Net Present Value of $44.2 million and a Benefit Cost Ratio (BCR) of 2.32. The overall project benefit matrix can be seen in Table ES-2.

Table ES-2: Project Impacts and Benefits Summary, Monetary Values in Millions of 2019 Dollars

Current Status/Baseline & Problem to be Addressed	Change to Baseline/ Alternatives	Type of Impact	Population Affected by Impact	Economic Benefit	Results Summary (2019$s, 7% disc)	Page Reference in BCA
Roadway congestion and current service frequency result in delays and longer wait times for transit users	The proposed improvements reduce average travel time of transit vehicles	Cost & Time Savings	Auto, Truck and Transit Users	Reduced travel time for transit users	$35.1 million	12
Current design of the roadway geometry results in greater congestion and idling for bus vehicles	The proposed improvements increase average travel speed and reduce idling	Vehicle Operating Cost	Auto, Truck and Bus Owners	Reduction in costs for fuel and vehicle maintenance	$1.1 million	15
		Emission Reduction	Community and road users	Reduction in costs related to air pollution	$0.5 million	18
Current roadway design facilitates conflict points between buses, autos, and bicyclists	The proposed improvements separate traffic in the corridor, reducing conflicts between road users	Crash Reduction	Road Users	Reduced crashes	$40.4 million	16
Reduced accessibility to the mainline bus infrastructure and services encourages demand for paratransit use	The proposed improvements improve accessibility by paratransit users to mainline bus services, reducing demand for paratransit services	Net Paratransit Operations Costs	MDOT	Reduced paratransit operations costs	$3.9 million	17

Source: WSP Analysis, 2021

The overall Project impacts can be seen in Table ES-3, which shows the magnitude of change and direction of the various impact categories.

Table ES-3: Project Impacts for Project, Cumulative 2025-2044

Category	Unit	Quantity	Direction
Vehicle-Miles Traveled	miles	7,370,753	▼
Person-Hours Traveled	hours	5,834,673	▼
Fuel Consumed	gallons	1,089,511	▼
Fatalities	#	5	▼
Injuries	#	377	▼
Property Damage Only (PDO)	#	1,001	▼
CO_2 Emissions	Tons	10,556	▼
NO_X Emissions	Tons	0.98	▼
$PM^{2.5}$	Tons	0.05	▼
SO_X	Tons	0.69	▼

In addition to the monetized benefits presented in Table ES-2, the Project would continue improving the accessibility and desirability of Baltimore's transit system for all users, while providing increased connectivity to social institutions and economic opportunities in the city. The performance improvements in the corridor could result in positive impacts throughout the transit system, encouraging multimodal connectivity for pedestrians and bicyclists throughout the city. While these benefits are not easily quantifiable, they provide advantages and improvements that will be experienced by individuals and businesses in the region.

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1 INTRODUCTION

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1.1 BCA FRAMEWORK

A BCA is an evaluation framework to assess the economic advantages (benefits) and disadvantages (costs) of an investment alternative. Benefits and costs are broadly defined and are quantified in monetary terms to the extent possible. The overall goal of a BCA is to assess whether the expected benefits of a project justify the costs from a national perspective. A BCA framework attempts to capture the net welfare change created by a project, including cost savings and increases in welfare (benefits), as well as disbenefits where costs can be identified (e.g., project capital costs), and welfare reductions where some groups are expected to be made worse off as a result of the proposed project.

The BCA framework involves defining a Base Case or "No Build" Case, which is compared to the "Build" Case, where the grant request is awarded and the project is built as proposed. The BCA assesses the incremental difference between the Base Case and the Build Case, which represents the net change in welfare. BCAs are forward-looking exercises which seek to assess the incremental change in welfare over a project lifecycle. The importance of future welfare changes is determined through discounting, which is meant to reflect both the opportunity cost of capital as well as the societal preference for the present.

The analysis was conducted in accordance with the benefit-cost methodology as recommended by the U.S. DOT in the 2021 Benefit-Cost Analysis Guidance for Discretionary Grant Programs.[1] This methodology includes the following analytical assumptions:

- Defining existing and future conditions under a No Build base case as well as under the Build Case;
- Estimating benefits and costs during project construction and operation, including 20 years of operations beyond the Project completion when benefits accrue;
- Using U.S. DOT recommended monetized values for reduced fatalities, injuries, property damage, travel time savings, and emissions, while relying on best practices for monetization of other benefits;
- Presenting dollar values in real 2019 dollars. In instances where cost estimates and benefits valuations are expressed in historical or future dollar years, using an appropriate inflation factor to adjust the values;
- Discounting future benefits and costs with a real discount rate of 7 percent consistent with U.S. DOT guidance.

1.2 REPORT CONTENTS

Section 2 of this report contains a description of the Project, information on the general assumptions made in the analysis, and a description of the base case compared to the build case. Section 3 provides a summary of the anticipated project costs. Section 4 reviews the expected economic benefits the Project would generate, including a review of the assumptions and methodology used to calculate the benefits. Finally, Section 5 reports the high-level results of the benefit-cost analysis.

[1] U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Applications, February 2021.

2 PROJECT OVERVIEW

2.1 DESCRIPTION

The ***East-West Priority Corridor Project*** is a multi-modal transportation enhancement project adding transit, pedestrian, and bicycle infrastructure improvements along a 20-mile opportunity corridor in Baltimore, Maryland. The Project applies strategies and design guidance from both the MDOT MTA Transit Priority Toolkit and the Baltimore City Complete Streets Manual to directly address existing challenges on a 20-mile corridor across Baltimore City and connects into Baltimore County carrying two of the region's highest-ridership bus routes. These improvements will facilitate faster and more reliable transit trips, strengthen multi-modal connections, and address existing pedestrian safety issues in order to enhance access and mobility to essential services, jobs, and schools in this priority corridor in Baltimore. The proposed improvements include the following:

- Dedicated bus lanes on 10 miles of the corridor;
- Transit signal priority and signal timing improvements;
- Bus stop enhancements, including shelters, benches and safety improvements;
- Wayfinding upgrades and real-time information;
- ADA improvements to sidewalks and bus stops;
- Pedestrian safety improvements, including curb extensions and pedestrian-scale lighting;
- A buffered, on-street bicycle lane connecting downtown Baltimore to a major transit hub in the corridor; and
- Electric vehicle charging stations.

MDOT MTA and BCDOT selected this corridor for significant transit, pedestrian, and bicycle infrastructure investment because of its potential to advance equity in the Baltimore region and expand transit access to over 180,000 jobs. The Project would shorten transit commute times and transit reliability for residents of some of the nation's highest-poverty communities and strengthen direct connections between these communities and employment centers, social services, education, and healthcare.

2.2 GENERAL ASSUMPTIONS

The evaluation period for the Project includes a 3-year design and construction period, from 2022 to 2026, during which capital expenditures are undertaken, plus 20 years of operations beyond Project completion through 2046.

Dollar figures in the analysis are expressed in constant 2019 dollars (2019$). In instances where certain cost estimates or benefit valuations were expressed in dollar values from other (historical) years, the U.S. Bureau of Economic Analysis' Implicit Price Deflator was used to adjust them to 2019 prices.[2]

The real discount rate used for this analysis was 7.0 percent, consistent with USDOT guidance for 2021 RAISE grants and OMB Circular A-94.[3]

[2] U.S. Bureau of Economic Analysis. Implicit Price Deflator, U.S. Average, Series CUSR0000SA0. 1982-1984=100
[3] White House Office of Management and Budget, Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs (October 29, 1992). (http://www.whitehouse.gov/omb/circulars_a094).

2.3 BASE CASE AND BUILD CASE

The analysis of the project segment considered how the balance of costs and benefits resulting from the construction of the project improvements would result in long-term benefits to its users and general society. In the "Build" Case, the Project includes:

- Conversion of 10 miles of general-purpose lanes into dedicated bus lanes
- Installation of signal priority and signal timing improvements
- Construction of bus stop infrastructure and installation of bus stop amenities
- ADA improvements to bus stops and sidewalks
- Building a 1.5-mile on-street buffered bicycle path along the Project corridor

These improvements are expected to shorten transit commute times, reduce pedestrian and vehicle crashes, and incentivize a percentage of auto users to shift to use bus services. Additionally, a percentage of paratransit users will shift to using mainline bus services, resulting in lower annual paratransit service costs. Due to the project's limited disturbance to existing roadways, construction-related closures, and early year disbenefits are not assumed to occur.

The "No Build" Case examines the societal costs of maintained auto traffic and transit ridership throughout the corridor without any planned safety or capacity improvements, resulting in continuation of historic crash levels, transit trip delays and roadway congestion levels.

3 PROJECT COSTS

3.1 CAPITAL COSTS

Initial project investment costs include design, construction, and soft costs totaling $50 million in year-of-expenditure dollars, or $46.3 million in undiscounted 2019 dollars. These costs are spread between 2022 and 2026 as shown in Table 1. For the purposes of this BCA, proposed improvements are assumed to be open and operational at the beginning of 2027.

Table 1: Project Costs by Category and Year, in Undiscounted Millions of 2019 Dollars

Cost Category	2022	2023	2024	2025	2026	Total
Bus Stops	-	-	-	$3.30	$3.30	$6.59
TSP	-	-	-	$0.28	$0.28	$0.57
Dedicated Bus Lanes	-	-	-	$6.33	$6.33	$12.66
Bike Facilities / Slow Streets	-	-	-	$2.31	$2.31	$4.62
Construction Start-Up Costs	-	-	-	$5.28	-	$5.28
Design Costs	-	$1.78	$1.78	-	-	$3.57
Soft Costs	$2.61	$2.61	$2.61	$2.61	$2.61	$13.05
Total	**$2.61**	**$4.39**	**$4.39**	**$20.11**	**$14.83**	**$46.34**
Total, Discounted 7%	**$2.28**	**$3.59**	**$3.35**	**$14.34**	**$9.88**	**$33.44**

Source: Maryland Department of Transportation Maryland Transit Administration (MDOT MTA), WSP

3.2 OPERATIONS, MAINTENANCE AND REHABILITATION COSTS

The annual costs of operating, maintaining, and rehabilitating the project are included in the analysis. The dedicated bus lanes are expected to require repainting every three years, beginning in 2030, at a cost of approximately $2 million per year. Over the analysis period, these costs are anticipated to total $12 million, or $3.9 million in present value when discounted using a 7 percent rate. Per U.S. DOT guidance, these costs are included as a negative benefit in the benefit-cost equation.

The project improvements are not anticipated to change the frequency or costs of annual maintenance to maintain the quality of the other assets associated with the project.

MDOT MTA will experience lower operating costs for the paratransit system due to ADA improvements at bus stops that will allow some paratransit riders to shift to fixed route service; these costs savings are described further and monetized in Section 4.3.

4 PROJECT BENEFITS

The benefits of the project improvements can be described as user benefits, including travel time savings and reduction in vehicle operating costs, and social benefits, including emissions reductions and the reduction in damage to property and injuries as the result of fewer collisions. The analysis covers the following benefit categories:

- Travel Time Savings
- Vehicle Operating Cost Savings
- Safety Benefits
- Agency Paratransit O&M Cost Savings
- Reduced Emissions

The analysis uses standardized factors provided by governmental and industry sources to efficiently determine the monetized value of user and social benefits resulting from the project improvements. These benefits include the reduction of existing costs or the prevention of future costs related to the operation and use of the existing corridor. Table 2 summarizes the benefit categories considered in the analysis.

Table 2: Project Benefits Summary

Benefit Category	Description	Monetized	Quantified	Qualitative
Travel Time Savings	Shortened transit commute times for existing and new riders	√		
Vehicle Operating Cost Savings	Auto users shift to transit services, reducing total vehicle operating costs	√		
Safety Benefits	Reduced crashes between buses, autos, and pedestrians	√		
Reduced Emissions	Reduction in auto trips reduces local vehicle emissions	√		
Agency Paratransit O&M Cost Savings	Existing paratransit users shift to mainline bus service, reducing annual operational costs	√		
ADA Access	Bus stations and sidewalks include improved ADA accessibility			√

4.1 ECONOMIC COMPETITIVENESS

The Project would contribute to increasing the economic competitiveness of the region by improving the mobility of people in the study area. Two types of societal benefits are measured in the assessment of economic competitiveness in this analysis: travel time savings and vehicle operating cost savings.

With the improvement in bus transit service resulting from the project improvements, travel time savings are a significant direct benefit for users within the corridor. The user benefits represent a reduction of future costs related to the use of the roadway. The shortening of transit commute time allows users to reach employment centers, retail locations and recreational activities in a cost- and time-efficient manner, impacting economic industries throughout the area. As a central component in improving the movement of persons throughout Baltimore City, the project improvements facilitate the improved connectivity to regional pedestrian and bicyclist infrastructure.

4.1.1 *TRAVEL TIME SAVINGS*

The Project will generate travel time savings primarily via dedicated bus lanes with transit signal priority, while curb extensions at three key stops along the corridor will also provide modest improvements. Total travel times savings over the analysis period equal $35.1 million in present value, as shown in Table 3. The assumptions and methodology used to calculate each of these is described below.

Table 3: Travel Time Savings Estimation of Benefits, Millions of 2019 Dollars

Type of Travel Time Savings	Project Opening Year		Project Lifecycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
DBLs - Existing Bus Passengers	$4.70	$2.92	$93.93	$31.16
DBLs - New Bus Passengers	$0.25	$0.16	$4.99	$1.76
Curb Extensions - Existing Bus Passengers	$0.024	$0.015	$0.47	$0.17
Curb Extensions - New Bus Passengers	$0.001	$0.001	$0.02	$0.01
Total	**$4.97**	**$3.10**	**$99.42**	**$35.10**

Source: WSP Analysis

DEDICATED BUS LANES WITH TRANSIT SIGNAL PRIORITY

By providing dedicated bus lanes and transit signal priority, the Project will significantly improve bus travel times along the corridor. These benefits are expected to occur primarily during the peak periods, when roadway congestion slows the speed at which buses can move between stops and requires buses to spend more time merging with traffic after each stop. Current peak travel times are expected to represent the future No-Build peak travel times. Under the Build scenario, peak travel time are assumed to be reduced to current off-peak travel times on the route.[4] Table 4 shows the estimated No-Build and Build peak hour travel time for each of the segments that will receive dedicated bus lanes as part of the Project.

[4] Analysis shows that the difference between current peak and off-peak travel time is primarily due to roadway traffic congestion and not dwell time at bus stops, which is similar throughout the day.

Table 4: Peak Hour Travel Time by Segment

Segment	No-Build Peak Travel Time	Build Peak Travel Time	Change in Peak Travel Time
Franklin St/Mulberry St and Martin Luther King Jr. Blvd to Edmondson Ave and Cooks Ln	25	18	7
Fayette St and Washington St to Fayette St and President St	9	4	5
Eastern Ave and Dundalk Ave to Eastern Ave and Bayview Blvd	5	3	2
Total	**39**	**25**	**14**

Source: WSP Analysis using Google Maps

These travel time savings are assumed to apply to the bus riders that travel along these segments during peak hours. The analysis uses trip load data by stop, collected by MDOT MTA in 2019, to estimate typical bus loads along the DBL segments, and multiplies these loads by the number of peak period buses on each segment to calculate the total number of daily passengers experiencing travel time savings as a result of the DBLs, shown in Table 5. No Build trip loads are expected to remain stable over time, returning to pre-pandemic levels by the time the bus lanes are operating and holding steady at that rate.

The number of daily passengers impacted is then multiplied by the change in peak travel time and by an annualization factor of 250 (reflecting all non-holiday weekdays) to arrive at total travel time savings from DBLs for existing users, shown in Table 6.

Table 5: Passengers Impacted by Dedicated Bus Lanes by Segment

Segment	Average Load on Segment	Number of Daily Buses	Daily Passengers Impacted	Annual Passengers Impacted
Franklin St/Mulberry St and Martin Luther King Jr. Blvd to Edmondson Ave and Cooks Ln	31.8	106.0	3,375	843,637
Fayette St and Washington St to Fayette St and President St	37.5	170.0	6,382	1,595,379
Eastern Ave and Dundalk Ave to Eastern Ave and Bayview Blvd	43.3	86.0	3,722	930,446
Total	**35.1**	**-**	**13,478**	**3,369,462**

Source: WSP Analysis of MDOT MTA Trip Load Data by Stop

Table 6: Dedicated Bus Lane Travel Time Savings by Segment

Segment	Total Daily Travel Time Savings (minutes)	Total Daily Travel Time Savings (hours)	Total Annual Travel Time Savings (hours)	Total Lifecycle Travel Time Savings (hours)
Franklin St/Mulberry St and Martin Luther King Jr. Blvd to Edmondson Ave and Cooks Ln	23,622	394	98,424	1,968,487
Fayette St and Washington St to Fayette St and President St	31,908	532	132,948	2,658,966
Eastern Ave and Dundalk Ave to Eastern Ave and Bayview Blvd	7,444	124	31,015	620,297
Total	**62,973**	**1,050**	**262,387**	**5,247,749**

Source: WSP Analysis

Finally, the improved travel times are expected to attract more riders to use the bus routes. The elasticity of transit demand with respect to travel time is assumed to be -0.6, while the change in total travel time is estimated to be approximately 13 to 17 percent (based on the change in travel times and total end-to-end corridor time for the impacted bus routes). This suggests that the travel time improvements can be expected to induce ridership

increases of 8 to 10 percent. These new riders are assumed to gain half the value of the per-trip travel time benefits, per USDOT guidance.

The assumptions used in the estimation of travel time savings and not yet shown in the previous tables are presented in Table 7.

Table 7: Travel Time Savings Assumptions and Sources

Variable	Unit	Value	Source
Value of Travel Time Savings – Existing Riders, All-Purposes	2019$ per person hour	$17.90	U.S. DOT BCA Guidance, February 2021
Value of Travel Time Savings – New Riders, All-Purposes	2019$ per person hour	$8.95	U.S. DOT BCA Guidance, February 2021
Travel Time Elasticity of Demand	Factor	-0.60	Victoria Transport Policy Institute, 2019
End-to-end travel time – Blue Line	Minutes	75	MTA, Blue Line Schedule
End-to-end travel time – Orange Line	Minutes	70	MTA, Orange Line Schedule
Annualization factor	Factor	250	N/A

Previous analysis of new bus lanes in Baltimore have found very modest impacts on general-purpose traffic, with some segments actually seeing reduced general-purpose travel times and average impacts across impacted segments of less than a minute per trip. Based on these results, impacts to general-purpose traffic are excluded from this analysis.

CURB EXTENSIONS

Curb extensions will be added to the following bus stops: Edmondson Avenue and Swann Avenue / Old Frederick Road, Lombard Street and Eaton Street, and Eastern Avenue and Elrino Street. Curb extensions are widened sidewalks that, when built at bus stops, expand the bus boarding area into the travel lane. By allowing buses to stop within the travel lane, buses avoid having to wait to re-enter traffic after stopping, creating travel time savings for bus riders. Each new curb extension is expected to save approximately 4 seconds per trip during peak hours.

These travel time savings are assumed to apply to the bus riders on board at each of the impacted stops. Table 8 shows the average peak-hour load at each stop, the number of daily peak-hour buses that stop at each bus stop, and the total daily and annual passengers calculated to experience the curb extension travel time benefits. Table 9 then summarizes the total curb-extension related travel time savings to be experienced by existing users daily, annually, and over the life of the project.

Table 8: Passengers Impacted by Curb Extensions by Bus Stop

Bus Stop	Average Load at Stop	Number of Daily Buses	Daily Passengers Impacted	Annual Passengers Impacted
Edmondson & Swann	23.3	42	977	244,195
Lombard & Eaton	44.4	43	1,911	477,820
Eastern & Elrino	46.7	40	1,868	466,875
Total	**114.4**	**-**	**4,756**	**1,188,890**

Source: WSP Analysis of MDOT MTA Trip Load Data by Stop

Table 9: Curb Extension Travel Time Savings by Bus Stop

Bus Stop	Total Daily Travel Time Savings (minutes)	Total Daily Travel Time Savings (hours)	Total Annual Travel Time Savings (hours)	Total Lifecycle Travel Time Savings (hours)
Edmondson & Swann	65	1.1	271	5,427
Lombard & Eaton	127	2.1	531	10,618
Eastern & Elrino	125	2.1	519	10,375
Total	**317**	**5.3**	**1,321**	**26,420**

Source: WSP Analysis

4.1.2 *VEHICLE OPERATING COST SAVINGS*

While some of the induced bus trips attracted by the faster speeds will be trips that would not otherwise have occurred, others are assumed to represent a shift from driving to riding the bus. Based on the average daily ridership on the impacted bus routes (shown in

Table 10), and the 8 to 10 percent induced ridership (calculated as described in Section 4.1.1), approximately 223,000 new trips are anticipated annually with the Project. Of these, 71.3 percent are expected to shift from automobiles (reflecting non-transit dependent riders), eliminating automobile trips of approximately 3.9 miles on average. Annual automobile VMT reductions thus total 312,000 miles.

Table 10: Vehicle Operating Cost Savings Assumptions and Sources

Variable	Unit	Value	Source
Average Daily Ridership 2019 – Blue Line	Trips	9,307	MDOT MTA
Average Daily Ridership 2019 – Orange Line	Trips	9,364	MDOT MTA
Annual New Bus Riders	Trips	223,000	Calculated from MDOT MTA data
Average Passenger Trip Length	miles/trip	3.92	FTA NTD, 2019 Service
Transit Dependency Factor	Factor	28.7%	US Census, Baltimore City, Households Size by Vehicles Available
Annual Auto Vehicle-Miles Avoided	vehicle-miles	312,000	Calculated from MDOT MTA, FTA and US Census data
Vehicle Operating Cost per Mile – Light Duty Vehicle	2019 dollars	$0.43	U.S. DOT Guidance, February 2021

These mode-shifted trips result in vehicle operating cost savings for the drivers, including the cost of fuel, as well as maintenance and repair, replacement of tires, and the depreciation of the vehicle over time. These costs are valued at $0.43 per mile, per USDOT guidance. Over the life of the project, vehicle operating cost savings total $1,119,000 in present value, as shown in Table 11.

Table 11: Vehicle Operating Cost Savings Benefits, Millions of 2019 Dollars

Benefit	Project Opening Year		Project Lifecycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Vehicle O&M Costs - Auto	$0.16	$0.10	$3.17	$1.12

Source: WSP Analysis

4.2 SAFETY

Improving safety for pedestrians, bicyclists, wheelchair users, and transit users on the East-West Priority Corridor is a central goal of this Project. Because the roadways along this route were originally designed for vehicle throughput with less of a focus on the safety of pedestrians, cyclists, and transit users, there are many opportunities to design for multi-modal safety on this corridor. The East-West Priority Corridor project addresses existing safety concerns through five primary scope elements:

- **Curb extensions** will decrease the crossing distance for pedestrians at intersections and slow vehicle speeds by visually and physically narrowing the roadway at major conflict points.
- **New crosswalks** at mid-block locations will provide safer crossings for pedestrians at locations with high pedestrian crash rates.
- **Dedicated bus lanes** reduce conflicts between buses and vehicles and have proven to reduce bus crashes in Baltimore.
- **ADA improvements** to bus stops allow people with mobility challenges to safely board and alight at bus stops by providing adequate space for wheelchairs and other mobility devices to navigate and board at the stop.
- **Protected bike lanes** will provide physically separated space for cyclists on a high-speed roadway, reducing crash risk by reducing conflict between cyclists and motor vehicles.

In this BCA, the benefits of the dedicated bus lanes and protected bike lanes are quantified, while the others can be described only qualitatively.

Under current conditions, the constriction of auto and transit vehicle traffic within the corridor results in crashes due to inattention, abrupt stops, and impatient driving. From 2017 to 2019, 1,248 automobile crashes occurred along the 20-mile project area, including 807 within the parts of the corridor where DBLs will be added. There were also 111 bus-involved crashes. In addition, two bicycle crashes took places in areas in which the Project will add bike lanes. The breakdown of average annual crashes by injury severity within the project area that will be directly impacted is shown below in Table 12.

Table 12: Crash History in Project Area by Type and Severity, Average 2017 to 2019

Crash Type	Severity of Injury	Total
Automobile	No Injury – O	191
	Possible Injury – C	70
	Non-Incapacitating – B	21
	Incapacitating – A	9
	Killed – K	1
Bicycle	Injury Severity Unknown	2
Bus	Property Damage Only (Blue Line)	37
	Property Damage Only (Orange Line)	74

Source: MDOT State Highway Administration; Baltimore Police Department

The analysis assumes crash rates modified with a crash modification factor reflective of the roadway improvements for the "Build" scenario. As a result, any changes in the number of crashes will be a result of structural changes to the safety conditions on the roadway network. The safety analysis applies a specific crash modification factor to the auto, bus and bicycle crashes based upon the project improvements affecting those vehicle types within the project area. The crash reduction by each vehicle type is shown below in Table 13.

Table 13: Reduction in Crashes in Project Area by Vehicle Type

Crash Type	Crash Modification Factor / Source	Crash Reduction (Percentage)	Annual Reduction in Crashes
Automobile	CMF ID #7274, Implement transit lane priority (at transit-serviced locations)	19.4%	72.6
Bicycle	CMF ID #4102, Install cycle tracks, bike lanes, or on-street cycling	59.0%	1.2
Bus	MTA, "Dedicated Bus Lanes Before and After Study", Feb 2019 (30% of Project Area)	11.8%	13.1

The construction of the dedicated bus lanes and the buffered bicycle lane within the corridor are projected to reduce crashes by approximately 79 incidents annually, or nearly 1,580 over the Project's life. The prevention of these crashes is expected to result in benefits of $40.4 million in discounted 2019 dollars, as shown in Table 14.

Table 14: Safety Benefits, Millions of 2019 Dollars

Crash Type	Project Opening Year		Project Lifecycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Automobile	$5.43	$3.38	$108.59	$38.33
Bicycle	$0.23	$0.15	$4.66	$1.65
Bus	$0.06	$0.04	$1.18	$0.42
Total Safety Benefits	**$5.72**	**$3.56**	**$114.43**	**$40.39**

Source: WSP Analysis

The assumptions used in the monetization of safety benefits are presented in the following table.

Table 15: Safety Benefits Assumptions and Sources

Variable	Unit	Value	Source
Cost of No Injury - O	2019$	$3,700	U.S. DOT Guidance, February 2021
Cost of Possible Injury - C	2019$	$72,500	U.S. DOT Guidance, February 2021
Cost of Non-Incapacitating - B	2019$	$142,000	U.S. DOT Guidance, February 2021
Cost of Incapacitating - A	2019$	$521,300	U.S. DOT Guidance, February 2021
Cost of Killed – K	2019$	$10,900,000	U.S. DOT Guidance, February 2021
Cost of Injured Severity Unknown	2019$	$197,600	U.S. DOT Guidance, February 2021
Cost of Property Damage Only Crash	2019$	$4,500	U.S. DOT Guidance, February 2021

4.3 AGENCY COST SAVINGS

The Project is expected to decrease the demand for paratransit services as a percentage of their existing users shift to using mainline bus services, following the installation of ADA-accessible bus stop improvements. Approximately 12 percent of the conditionally eligible paratransit users living within a quarter mile of new and existing bus stops throughout the corridor for the Blue and Orange lines are expected to shift over to mainline bus services. The breakdown of users expected to shift from using paratransit services to mainline bus services is detailed below in Table 16.

Table 16: Agency Paratransit Services Assumptions and Sources

Variable	Unit	Value	Source
Total Annual Paratransit Trips 1/4 Mile of Orange and Blue Lines	passengers	202,380	MTA Operations, 2020 (Trapeze)
Percent of Paratransit Trips Conditionally Eligible	passengers	50%	MTA Operations, 2020 (Trapeze)
Percent of Paratransit Trips Shift to Orange and Blue Lines	passengers	12%	TCRP Report 163, "Strategy Guide to Enable and Promote the Use of Fixed-Route Transit by People with Disabilities"
Total Annual Paratransit Trips Shift to Orange and Blue Lines	passengers	12,143	Calculation
Paratransit Services Operating Expenses 2019	2019 dollars	$111,623,095	FTA NTD, MTA 2019 Operating Expenses
2019 Paratransit Trips	Unlinked passenger-trips	2,135,482	FTA NTD, MTA 2019 Service
Operating cost per trip	2019 dollars per paratransit trip	$52.27	Calculation

Each paratransit trip avoided is expected to save MTA approximately $52. Thus, the agency's benefit over the entire project lifecycle from the reduced demand for paratransit services is valued at $12.7 million undiscounted 2019 dollars and $4.5 million in present value when discounted using a 7 percent rate.

Table 17: Paratransit Cost Savings Benefits, Millions of 2019 Dollars

Benefit	Project Opening Year		Project Lifecycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Paratransit Cost Savings	$0.63	$0.40	$12.69	$4.48

Source: WSP Analysis

4.4 ENVIRONMENTAL SUSTAINABILITY

The Project will create environmental sustainability benefits relating to reduction in vehicle emissions associated with fewer auto and paratransit trips and more efficient bus speeds. The decrease in the number of vehicles on the road and the faster average speed of transit vehicles reduces the overall tonnage of emissions from the vehicles. The assumptions used to calculate and monetize the change in vehicle emissions are shown below in Table 18.

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Table 18: Emissions Benefits Assumptions and Source

Variable	Unit	Value	Source
Average Travel Speed of Bus Vehicles (Build)	MPH	10.2	MDOT MTA Bus Operations
Average Travel Speed of Bus Vehicles (No Build)	MPH	6.8	MDOT MTA Bus Operations
Annual Auto Vehicle-Miles Avoided	vehicle-miles	495,800	Calculated from MDOT MTA, FTA and US Census data
2019 Paratransit Passenger Miles	Passenger miles	21,841,558	FTA NTD, MTA 2019 Service
2019 Paratransit Trips	Unlinked passenger-trips	2,135,482	FTA NTD, MTA 2019 Service
Paratransit Miles per Trip	Miles per trip	10.23	Calculation
Annual Paratransit Miles Avoided	Vehicle miles	124,196	Calculation
Emissions per VMT for NOx, PM2.5, and Sox	Grams per VMT	Varies by year, vehicle type, speed, and emission type	California Air Resources Board EMFAC Database, 2017
CO2 emissions per gallon of gasoline	lbs. per gallon	8,887	U.S. EPA, Greenhouse Gas Equivalencies Calculator
CO2 emissions per gallon of diesel	lbs. per gallon	10,180	U.S. EPA, Greenhouse Gas Equivalencies Calculator
Fuel efficiency	gallons per mile	Varies by year and vehicle type	U.S. EIA, Annual Energy Outlook 2021 and
Fuel efficiency factor	factor	Varies by type of vehicle and speed	U.S. EIA 2013
Cost of CO2 emissions	2019$ per metric ton	$50 (in 2020) - $84 (in 2050)	U.S. DOT Guidance, February 2021
Cost of NOx emissions	2019$ per metric ton	$15,700 (in 2020) - $18,000 (in 2050)	U.S. DOT Guidance, February 2021
Cost of PM2.5 emissions	2019$ per metric ton	$729,300 (in 2020) - $852,700 (in 2050)	U.S. DOT Guidance, February 2021
Cost of SOx emissions	2019$ per metric ton	$40,400 (in 2020) - $48,200 (in 2050)	U.S. DOT Guidance, February 2021

Four forms of emissions were identified, measured, and monetized, including: nitrous oxide (NOx), particulate matter (PM2.5), sulfur dioxide (SO2), and carbon dioxide (CO2). The benefit of the emissions reduction from the project is valued at $510,000 in discounted 2019 dollars, as shown in Table 19.

Table 19: Benefits of Emissions Reductions, Millions of 2019 Dollars

Benefit	Project Opening Year		Project Lifecycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
CO2 Emissions Reduction	$0.034	$0.028	$0.72	$0.44
NOx Emissions Reduction	$0.001	$0.001	$0.02	$0.01
SOx Emissions Reduction	$0.002	$0.002	$0.03	$0.01
PM2.5 Emissions Reduction	$0.004	$0.003	$0.04	$0.02
Total Emissions Reduction	**$0.043**	**$0.033**	**$0.81**	**$0.48**

Source: WSP Analysis

5 SUMMARY OF RESULTS

5.1 EVALUATION MEASURES

The benefit-cost analysis converts potential gains (benefits) and losses (costs) from the Project into monetary units and compares them. The following common benefit-cost evaluation measures are included in this BCA:

- Net Present Value (NPV): NPV compares the net benefits (benefits minus costs) after being discounted to present values using the real discount rate assumption. The NPV provides a perspective on the overall dollar magnitude of cash flows over time in today's dollar terms.
- Benefit Cost Ratio (BCR): The evaluation also estimates the benefit-cost ratio; the present value of incremental benefits is divided by the present value of incremental costs to yield the benefit-cost ratio. The BCR expresses the relation of discounted benefits to discounted costs as a measure of the extent to which a project's benefits either exceed or fall short of the costs.
- Internal Rate of Return (IRR): The IRR is the discount rate which makes the NPV from the Project equal to zero. In other words, it is the discount rate at which the Project breaks even. Generally, the greater the IRR, the more desirable the Project.
- Payback Period: The payback period refers to the period of time required to recover the funds expended on a Project. When calculating the payback period, the time value of money (discounting) is not taken into account.

5.2 BCA RESULTS

Table 20 presents the evaluation results for the project. Results are presented in undiscounted, discounted at 7 percent as prescribed by the U.S. DOT. All benefits and costs were estimated in constant 2019 dollars over an evaluation period extending 20 years beyond system completion in 2026. The total benefits from the project improvements within the analysis period are calculated to be $77.7 million in discounted 2019 dollars. The total capital costs, including design and construction, are calculated to be $33.4 million in discounted 2019 dollars. The difference of the discounted benefits and costs equal a net present value of $44.2 million in discounted 2019 dollars, resulting in a benefit-cost ratio (BCR) of 2.32. These results indicate that the benefits far exceed the project costs, and that the project is a worthwhile investment.

Table 20: Benefit Cost Analysis Results, Millions of 2019 Dollars

BCA Metric	Undiscounted	Discounted (7%)
Total Benefits	**$218.5**	**$77.7**
Travel Time Savings	$99.4	$35.1
Vehicle Operating Cost Savings	$3.2	$1.1
Safety Benefits	$114.4	$40.4
Emissions Reduction	$12.7	$4.5
Paratransit Cost Savings	$0.8	$0.5
Agency OM&R Costs	($12.0)	($3.9)
Total Costs	**$46.3**	**$33.4**
Net Present Value (NPV)	**$172.2**	**$44.2**
Benefit Cost Ratio (BCR)	**4.72**	**2.32**
Internal Rate of Return (IRR)	**19%**	
Payback Period (Years)	**9.2**	

Source: WSP Analysis