APPENDIX A:
Benefit Cost Analysis

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Benefit-Cost Analysis Technical Memorandum

CO 119 Diagonal Highway Mobility Improvements Project

2022 RAISE Grant Program

Prepared for: Muller Engineering

April 2022

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1. Introduction

A benefit-cost analysis (BCA) was conducted for the CO 119 Diagonal Highway Mobility Improvements Project (CO119 Project) to support the discretionary grant application for the U.S. Department of Transportation's (DOT) 2022 RAISE grant program. This analysis was conducted in accordance with the DOT's 2022 Benefit-Cost Analysis Guidance for Discretionary Grant Programs for a 23-year assessment period beginning with capital outlays in 2024 through to 2026 and operations from 2026 to 2046.[1] Capital outlays are currently estimated at approximately $124 million in year or expenditure dollars (approximately $99 million base year dollars).

The Project will provide critical intersection improvements and implement Bus Rapid Transit (BRT), connecting the counties of Larimer, Weld, and Boulder (Rural Communities) in the North Front Range of Colorado. The planned improvements promote safe, efficient, and equitable mobility options for people and goods traveling by car, truck, transit, bicycle, and on foot, essential to the improved prosperity and sustainability of the region.
CO 119 provides an essential link between Boulder and Longmont and is a critical regional corridor that serves all travel modes between the two cities and activity centers along the corridor. In addition to motor vehicle traffic, the corridor currently carries a significant number of daily transit users and cyclists.

Major components of the Project that will be considered for RAISE funds include:

- Queue bypass lanes and TSP at all signalized intersections except for Hover Street and northbound Airport Road;
- Signalized intersection improvements at (Jay Road, 63rd Street, CO 52, Niwot Road, Airport Road, and Hover Street);
- Innovative design of inside BRT lanes;
- Upgrading traffic signal poles at all intersections;
- Modification to a split intersection configuration at CO 52 to increase intersection operations/reduce congestion of the largest bottleneck in CO 119 and accommodate BRT and separated bikeway needs;
- Converting lanes at the Airport Road intersection to more one-way movements in line with heavy traffic patterns to achieve vehicular, transit, bicycle, and pedestrian operational and safety benefits;
- Park-n-Ride facilities at 63rd Street, CO 52, and Niwot Road;
- BRT stations at 63rd Street, CO 52, and Niwot Road;
- Tunnel for through traffic at Hover Street with a grade-separated bicycle/pedestrian facility to run parallel to the vehicle tunnel;
- Improving pedestrian safety and access with signing, striping, and lighting at all crossings;
- Construction of four bikeway over/underpasses and one segment of the bikeway (between Jay Road and 63rd Street); and
- Implementation of safety recommendations throughout CO 119.

The analysis evaluates the generation of a diverse basket of economic benefits resulting from the delivery of the build scenario when compared to the baseline scenario. In the baseline scenario, no action is undertaken and operations along CO 119 will continue as normal. In this scenario, increased congestion along CO 119 will lead to gradually slower travel times along the corridor for all users with these slower travel times most pronounced for transit users. In the build scenario, the works described above will be developed over a thirty-month period beginning in 2024 and through to 2026, with operations beginning in the summer of 2026.

[11] USDOT Benefit Cost Analysis Guidance for Discretionary Grant Programs, March 18, 2022 https://www.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

The realization of the Project will deliver a variety of benefits, most notably a decrease in vehicle hours traveled (VHT), a reduction in vehicular accidents including those involving cyclists, fuel savings, and the reduction in emissions.

Notable economic benefits that the Project will deliver, consistent with the overarching long term outcomes criteria sought after by the DOT's RAISE program, include the following summarized in Table 1-1.

Table 1-1 Key Benefits Delivered by Long Term Outcomes (2026-2046)

CO 119 Diagonal Highway Mobility Improvements Project	
Benefit	**$M (2020)**
Economic	
Travel Time Savings - Autos	$59.8
Travel Time Savings - Commercial Truck	$2.0
Travel Time Savings - Transit	$10.2
Operating Cost Savings - Commercial Truck	$2.8
Operating Cost (Additional) - Transit Bus Service	-$9.2
Fuel Savings - Autos	$3.4
Environmental	
Reduced Emissions - Automobiles	$0.7
Reduced Emissions - Commercial Truck	$0.2
State of Good Repair	
Net increase in O&M	-$0.4
Residual	$5.0
Safety	
Reduced Accidents	$51.7
Total Benefits	**$126.2**
Costs	
Capital Costs	$89.7
Total Costs	**$89.7**
Benefit Cost Analysis	
Net Present Value ($M)	**36.4**
Benefit Cost Ratio	**1.41**

Source: AECOM

2. Benefit Analysis Assumptions

The BCA evaluates the benefits and costs of implementing the Project against the no action scenario in which the Project does not occur. The analysis utilizes information from a number of sources from both government agencies and consultants engaged by the applicant, as well a number of assumptions which are compliant with the latest USDOT guidance.

2.1. Analytical Assumptions

2.1.1. Assumptions – General

2.1.1.1. Discounted Rates

Consistent with the DOT's guidance for discretionary grants, a real discount rate of 7 percent was used for this analysis. Project investments are expressed year of expenditure dollars, in constant 2020 dollars, and in discounted 2020 dollars. In instance where assumptions or cost estimates are expressed in dollar values for other years, the assumed escalation rate of 4.857% per annum has been used to bring these to 2020-dollar figures. Calculations including benefit valuations for future years are expressed in 2020 dollars with the Chained Price Index information from the White House Office of Management and Budget's Gross Domestic Product and Deflators have been used to bring these to 2020.[2]

2.1.1.2. Evaluation Period

The evaluation period in this assessment is 24 years, extending from 2024 through to the middle of 2046. This evaluation period begins in the year in which capital expenditures for the Project began, plus twenty years of operations of the infrastructure improvements and other associated works of the Project. This analysis assumes that construction of the Project begins in 2024 and will continue through to mid-2026 after which operations will begin immediately. All benefits and costs are assumed to occur at the end of the year, including both 2026 and 2046, even though assessed benefits are only taken for half of each of those years.

2.1.1.3. Key Benefit-Cost Evaluation Measures

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

Net Present Value (NPV)

NPV compares the net benefits (benefits less 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 2020 dollars (2020$).

Benefit Cost Ratio (BCR)

The BCR expresses the relation of discounted benefits to discounted costs as a measure of the extent to which the project benefits either exceed or fall short of their associated costs.

2.1.2. Assumptions – Travel Demand and Travel Times

Traffic operations modelling for the Project corridor was undertaken by Apex Design and provided to AECOM as inputs for the benefit cost model. The travel modelling considered both traffic volumes and travel times in 2019 and in 2045 through the Project Corridor under scenarios – the baseline on no-build scenario in which the Project's improvements are not implemented, and the build scenario in which the Project's improvements are implemented.

APEX Design travel demand modelling considered 2019 and 2045 traffic metrics across both scenarios. Information used form the APEX Design modelling output comprised gross daily vehicle numbers, vehicle miles travelled (VMT)

[2] White House Office of Management and Budget. Historical Tables, Table 10.1 – Gross Domestic Product and Deflators Used in the Historical Tables 1940-2027. Accessed from https://www.whitehouse.gov/wp-content/uploads/2022/03/hist10z1_fy2023.xlsx

along the Project corridor, and vehicle hours travelled (VHT). A summary of the inputs from the travel demand modelling are shown in Table 2-1.

Table 2-1 Travel Model Outputs (Daily Vehicle numbers, VMT,VHT) Baseline and Build Scenarios – CO119 Project

Metric	2019 Existing Conditions		2045 No Build		2045 Transit Slip Lanes	
	AM	PM	AM	PM	AM	PM
Vehicles Fully Processed	54,882	61,880	68,470	77,053	68,477	76,863
Vehicle Miles Traveled (VMT)	238,644	261,674	287,844	321,637	288,246	320,656
Vehicle Hours Traveled (VHT)	6,002	6,651	8,211	10,942	7,703	9,304

Source: APEX Design (2022)

The percentage of commercial truck traffic for the corridor was sourced from Colorado Department of Transportation's Online Transportation Information System (OTIS) and this percentage – 3.6% - multiplied by the total vehicle daily vehicle volumes to derive commercial truck numbers, VMT, and VMT. A similar process was undertaken with transit users using current and future ridership estimated from RTD. Both commercial truck and transit users were subtracted from the total daily number of vehicles prior to any further calculations.

2.1.2.1. Travel Time Savings

Travel time savings were estimated by APEX Design and were inter- and extrapolated from the 2019 and 2045 estimates. The savings in VHT were then allocated by cars, commercial trucks, and transit users according to the volume of each mode as previously described. This allows the analysis to account for different savings on passengers, commercial drivers, and transit users.

2.1.2.2. Annualization Factor

An annualization factor of 260 days of operations per annum has been assumed, representative of congestion along the Project corridor being most pronounced during weak day peak hour and shoulder periods.

2.1.2.3. Value of Time

Travel time savings are converted from hours to dollars. This is performed by assuming that travel time is valued as a percentage of the average wage rate, with different percentages assigned to different trip purposes. This analysis used the USDOT 2022 all purposes value of $17.80 per hour for automobile drivers, their passengers, and transit users. For commercial drivers, the analysis uses the USDOT 2022 value of $32.00 per hour. These rates were based on the DOT's Recommended Hourly Value of Travel Time Savings, as shown below at Table 2-2.

Table 2-2 Hourly Value of Travel Time Savings, All Users (2018 $ per person-hour)

Category	Hourly Value
Value of Time - All Purposes (2020$)	$17.80
Value of Time – Commercial Truck Drivers (2020$)	$32.00

Source: US Department of Transportation (2022)

2.1.2.4. Vehicle Miles Travelled (VMT)

Vehicle miles travelled (VMT) are used in a variety of benefits and costs categories, including operating cost and emissions. In both, the baseline and build scenarios, the total VMT for 2019 and 2045 were modelled and inter-/extrapolated for each year of the analysis period.

2.1.2.5. Vehicle Hours Travelled (VHT)

Vehicle hours travelled (VHT) is used in a variety of benefits and costs categories, including travel time savings. Vehicle hours used in this analysis comprise the estimates of travel times avoided for auto, commercial trucks, and transit users under the baseline and build scenarios.

2.1.2.6. Average Vehicle Occupancy

Average vehicle occupancy allows for the estimation of total travel time savings. This analysis assumes an average vehicle occupancy of 1.67 for autos under the build and baseline scenario, as taken from the DOT's 2022 BCA Guidance.

2.1.3. Assumptions – Safety

Muller Engineering undertook an analysis of the safety benefits the Project would generate. This analysis was carried out on an individual basis for each of the eleven major components of the Project, with crash modification factors (CMFs) for each improvement applied. Each crash modification factor was sourced from the FHWA's Crash Modification Factor Clearinghouse. The safety analyses utilized 2020 and 2045 ADT information sourced from CDOT's OTIS, daily traffic volumes interpolate for the years between 2020 and 2045, annualized, and CMFs applied. The total reduction in crashes, injuries, and fatalities avoided as a result of the implementation of the Projects was calculated for the years 2026-2046, then aggregated in the Project wide safety summary.

Crash types were monetized in accordance with USDOT guidance, which is shown in Table 2-3.

Table 2-3 Crash Type Values

Crash Type	Monetized Value
Property Damage Only (PDO) Crashes (per vehicle)	$4,600
Injury Crash	$302,600
Fatal Crash	$12,837,400

Source: US Department of Transportation (2022)

2.1.4. Assumptions – Infrastructure Operation and Maintenance

2.1.4.1. Operations and Maintenance Costs – Roads

In the build scenario, approximately 4.9 miles on new road lane miles would be constructed and there would be additional operations and maintenance costs incurred associated with these additional lane miles. Historically, CDOT has spent $15,001 per lane mile per year for existing streets and highways, but only $7,606 per lane mile per year for newly rehabilitated streets and highways.[3] It has been assumed that the additional lane miles in the build scenario will incur additional operations and maintenance costs for the first tens years of operation at $15,001 per annum and $7,606 per annum for years 11-20.

2.1.4.2. Operation Costs Transit

Denver's Regional Transit District (RTD) has estimated that, following completion of the Project and the installation of the new transit queue jump lane, the number of transit operations on the Blue and Orange line will increase from 87 to 96. To account for these additional transit services, the benefit costs analysis assumes that each service will comprise 5 and a third hours of operation a day, equating to 48 total additional hours of transit operation per day. This was then annualized and applied to the hourly cost of transit operation, $106, as taken from RTD's 2021 Annual Budget.

2.1.5. Assumptions – Residual Value

The Project infrastructure is comprised of a several different type of infrastructure improvements and many components for resulting infrastructure would have useful lives that extend beyond the 20-year assessment period, as determined by the Bureau of Economic Analysis (BEA), and therefore have residual value at the end of the analysis period.

[3] 2017 figures of $14,200 and $7,200 have been escalated to current year dollars using the OMB deflator.

Table 2-4 Assumed Useful Life of Assets – Assessment Corridor

	Asset Life	Asset Life Remaining
Structures (Bridge Underpass and Walls)	75	30
Concrete and Structures (Non-Bridge)	50	30
Asphalt	30	10
Signal Systems and Signage	30	10
Drainage	50	30

Source: BEA, USDOT Bridge Preservation Guide

2.1.6. Assumptions – Vehicle Operations – Transit and Commercial Trucks

The implementation of the Project and its operations will result in faster travel times for auto users and their passengers, transit users, and commercial drivers. Despite these faster travel times, the benefit cost analysis only calculated operation cost savings for commercial drivers. Vehicle operating costs comprise both fuel and non-fuel costs for commercial vehicles, as taken from the 2021 American Transportation Research Institute's *Operational Cost of Trucking 2021,* and have an assessed value of $43.90 per hour.[4]

As discussed in section 2.1.4.2, transit operating costs are expected to increase reflective of additional hours of operation associated with additional transit services operating in the Project corridor.

2.1.7. Assumptions – Emissions

Changes in VHT as a consequence of the Project will create environmental and sustainability impacts relating to automobile and commercial trucks. Four types of emissions are identified, measured and monetized: volatile organic compounds (VOC), particulate matter (PM2.5), carbon dioxide (CO_2) and nitrogen oxide (NOx).

2.1.7.1. Emissions Quantification

Emission rates differ between vehicle types and depending on fuel efficiency, average speed, and driving conditions. This analysis uses emissions factors from the Environmental Protection Agency (EPA) which provides emissions factors for automobiles and commercial trucks.

This analysis quantifies emissions generated under the baseline and build scenario utilizing VHT. Faster travel times by personal vehicles and commercial vehicles due to the Project will generate a reduction or increase in emissions.

Emission factors for automobiles utilize the EPA guidance which assumes that emissions will decrease on a per VHT basis over time due to better fuel efficiency. Emissions were calculated both on grams emitted per hour travelled and per gallon of fuel used. An overview of the assumed emission factors for automobiles for this analysis is shown in Table 2-5.

Table 2-5 Emission Factors (g/VMT) for Automobiles and Commercial Trucks

Pollutant	Units	Autos	Commercial Truck
VOC	g/hr	3.5	3.5
NOx	g/hr	3.8	33.8
PM2.5	g/gallon	0.1	1.114
PM10	g/gallon	0.1	1.211
CO2	g/gallon	8,877	10,180

Source: EPA

[4] Table 9 ATRI Operational Cost of Trucking 2021. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance. Excludes driver time (valued in travel time savings); https://truckingresearch.org/2021/11/23/an-analysis-of-the-operational-costs-of-trucking-2021-update/

2.1.7.2. Emissions Valuation Approach

Values for each emission type, except for CO_2, were sourced from the USDOT's *2022 Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. An overview of the economic values used for each emission type is shown in Table 2-6.

Table 2-6 Recommended Monetized Value(s) by Emission Type

Value of Emissions Reduced	2020$	Unit
Carbon Monoxide (CO_2)	$0	$/metric ton
Volatile Organic Compounds (VOCs)	$56-82	$/metric ton
Nitrogen Oxides (NOx)	$16,800 - 18,100	$/metric ton
Particulate Matter ($PM_{2.5}$)	$814,500 – 867,700	$/metric ton

Source: US Department of Transportation (2022)

3. Outcomes

3.1. Safety Outcomes

Safety outcomes comprise the increase or reduction in the incidence of accidents, injuries, and fatalities as consequence of the implementation of the CO119 Project. The baseline and build scenarios both forecast increased traffic volumes over time; however, the build scenario incorporates a number of infrastructure improvements which will result in safer traffic operations over the assessment period, including the avoidance of more than four fatalities.

Table 3-1 shows the total decrease of accidents associated with the construction of the CO119 Project its first twenty years of operations.

Table 3-1 Reduction in Accidents (2026-2046)

Year	Accidents Avoided		
	PDO	Injuries Reduced	Fatalities Reduced
2026 (half)	9.3	6.2	0.1
2027	18.8	12.6	0.2
2028	19.0	12.7	0.2
2029	19.2	12.8	0.2
2030	19.4	12.9	0.2
2031	19.6	13.0	0.2
2032	19.8	13.2	0.2
2033	20.0	13.3	0.2
2034	20.2	13.4	0.2
2035	20.4	13.5	0.2
2036	20.6	13.6	0.2
2037	20.8	13.7	0.2
2038	21.0	13.8	0.2
2039	21.3	13.9	0.2
2040	21.5	14.0	0.2
2041	21.7	14.1	0.2
2042	21.9	14.2	0.3
2043	22.1	14.3	0.3
2044	22.3	14.4	0.3
2045	22.5	14.5	0.3
2046 (half)	11.3	7.2	0.1
Total	**402.2**	**264.4**	**4.6**

Source: AECOM

3.2. Economic Outcomes

3.2.1. Travel Time Savings

Travel time savings estimations were derived from APEX Design's travel model outputs. Travel time savings were interpolated and extrapolated from the 2019 and 2045 baseline and build scenario estimates. For the analysis period, the changes in travel time for the build scenario as compared with the baseline scenario have been summarized in Table 3-2. These figures were distributed for automobile drivers and passengers, commercial truck drivers, and transit users.

Table 3-2 Travel Time Savings Resulting from Implementation of the Build Scenario (2026-2046)

Year	Annual Reduction in Travel Times (Hours)		
	Autos and Passengers	Commercial Drivers	Transit Users
2026 (half)	95,209	1,910	22,440
2027	220,509	4,398	52,739
2028	251,368	4,985	61,007
2029	283,007	5,581	69,700
2030	315,443	6,186	71,668
2031	348,692	6,799	73,692
2032	382,769	7,421	75,773
2033	417,691	8,053	77,913
2034	453,475	8,693	80,113
2035	490,137	9,343	82,376
2036	527,694	10,002	84,702
2037	566,164	10,670	87,094
2038	605,566	11,348	89,554
2039	645,916	12,036	92,083
2040	687,234	12,734	94,683
2041	729,538	13,441	97,357
2042	772,848	14,158	100,106
2043	817,183	14,885	102,933
2044	862,562	15,623	105,840
2045	898,249	16,371	108,829
2046 (half)	472,608	8,564	55,951
Total	**10,843,862**	**203,203**	**1,686,556**

Source: APEX Design, AECOM

3.2.1.1. Travel Time Savings – All Modes

Travel time savings for autos and passengers, commercial truck drivers, and transit users were calculated by applying the travel time reductions for each, as shown in Table 3-2, and then applying these to the USDOT recommended value of time for each of those modal users. An overview of the total travel time reduction savings resulting from the implementation of the Project, is shown in Table 3-3.

Table 3-3 Travel Times Savings (2026-2046)

	Time Savings - (2022$)	Discounted Time Savings (7%)
Auto Drivers and Passengers	$ 193,020,751	$ 59,756,437
Commercial Drivers	$ 6,502,483	$ 2,035,627
Transit Users	$ 30,020,688	$ 10,157,071
Total Savings	$ 229,543,923	$ 71,949,135

Source: AECOM

3.2.2. Operating Cost Savings

More efficient operations along the CO119 corridor due to the implementation of the Project will lead to commercial truck incurring operational cost savings due to a reduction in VHT. An overview of the total operational cost savings is shown in Table 3-3.

Table 3-4 Operational Cost Savings – Commercial Trucks (2026-2046)

	Operational Cost Savings - (2022$)	Discounted Operational Cost Savings (7%)
Commercial Trucks	**$8,920,594**	**$2,792,625**

Source: ATRI (2021), AECOM

3.2.3. Fuel Savings

More efficient operations along the CO119 corridor due to the implementation of the Project will lead to fuel savings for automobiles due to a reduction in VHT. An overview of the fuel savings is shown in Table 3-3.

Table 3-5 Fuel Savings - Automobiles (2026-2046)

	Fuel Savings (Gallons)	Fuel Savings - (2022$)	Discounted Fuel Savings (7%)
Automobiles	2,570,480	$10,934,824	$3,383,123

Source: ATRI (2021), AECOM

3.3. Environmental outcomes

3.3.1. Emissions Reduction

The build scenario CO119 Project will result in all modes of vehicular traffic travelling with greater efficiency along the study corridor. Travelling at more consistent speeds will result in more efficient use of fuel and thus lower emissions. A summary of the emissions reduction associated with improvements in vehicle hours travelled is shown in Table 3-6.

Table 3-6 Emissions Due to Changes in Vehicle Hours Travelled (2026-2046)

	Auto	Truck	Total
VOC (metric tons)	22.60	0.79	23.39
NOx (metric tons)	24.71	7.70	32.41
$PM_{2.5}$ (metric tons)	0.23	0.20	0.43
PM_{10} (metric tons)	0.22	0.22	0.45
CO2 (metric tons)	22,818	1,858	24,676

Source: APEX Design, EPA, AECOM

4. Cost Analysis

The costs assessed in this analysis comprise capital costs and those associated with the operation and maintenance of the CO 119 Project.

4.1. Capital Cost

The capital costs include the constriction, right of way acquisition and utilities relocation, and soft costs which includes: final design and engineering, project management, and construction management This total capital outlays are estimated at approximately $124.2 million in YOE, $98.8 million in real $2020 dollars with the 4.857% per annum escalation stripped out, and $89.7 million when discounted back to $2020 at 7% from the year of expenditure. An overview of the Project's capital costs by component in YOE dollars is shown in Table 4-1.

Table 4-1 Capital Cost for CO119 Project by Component

CO119 Component	Total ($M YOE)	Construction	Right of Way/Utilities	Soft Costs
INT-SH52	$ 28.55	$19,707,484	$1,407,356	$7,431,295
QJ-Jay	$ 8.65	$6,324,415		$2,322,339
QJ-63rd	$ 11.25	$8,202,548		$3,050,078
QJ- SH52 (Mineral)	$ 7.70	$5,613,037		$2,086,128
QJ-Niwot	$ 7.58	$5,530,961		$2,049,756
QJ-Airport	$ 0.59	$395,977		$196,266
INT Airport	$ 0.93	$637,163		$294,298
Minor Intersection Improvements (x3)	$ 0.31	$214,873		$92,088
Bikeway-Jay to 63rd & 4 Underpasses	$ 18.80	$13,388,132		$5,407,387
Hover Street Intersection	$ 28.54	$18,420,040		$10,116,384
RTD - Park n Ride (x2)	$ 6.77	$5,465,169	$48,380	$1,259,639
RTD - Platforms (x 3)	$ 4.35	$3,328,526	$54,427	$971,239
Total	$124.02	$87,228,326	$1,510,164	$35,276,897

The capital costs are expected to be expended according to the project schedule with construction beginning in 2024 and ending in Q2 of 2026. An overview of the schedule of expenditure by year is shown in Table 4-1.

Table 4-2 Schedule of Expenditure for CO119 Project ($YOE)

Year	2024	2025	2026	Total
Quarters of Expenditure	4	4	2	10 (30 months)
Yearly Expenditure ($YOE)	$49,606,155	$ 49,606,155	$24,803,077	$124,015,387

4.2. Operating and Maintenance Cost

The construction and operation of the CO119 Project will result in moderately higher operations and maintenance costs associated with additional lane miles and additional hours of operation for transit bus services.

An overview of the increase in the annual cost of operations and maintenance costs of the Project corridor across the assessment period is summarized in Table 4-33. An overview of the increase in the operations costs for transit is shown in Table 4-4

Table 4-3 Annual Operations and Maintenance Costs – CO119 Project (2026-2046)

Year	Annual Existing O&M Costs	Annual Build Scenario O&M Costs	Additional Annual O&M	Discounted at 7%
2026	$147,311	$165,984	$(18,673)	$(12,443)
2027	$294,622	$331,968	$(37,346)	$(23,257)
2028	$294,622	$331,968	$(37,346)	$(21,736)
2029	$294,622	$331,968	$(37,346)	$(20,314)
2030	$294,622	$331,968	$(37,346)	$(18,985)
2031	$294,622	$331,968	$(37,346)	$(17,743)
2032	$294,622	$331,968	$(37,346)	$(16,582)
2033	$294,622	$331,968	$(37,346)	$(15,497)
2034	$294,622	$331,968	$(37,346)	$(14,484)
2035	$294,622	$331,968	$(37,346)	$(13,536)
2036	$294,622	$331,968	$(37,346)	$(12,651)
2037	$294,622	$368,277	$(73,655)	$(23,317)
2038	$294,622	$368,277	$(73,655)	$(21,792)
2039	$294,622	$368,277	$(73,655)	$(20,366)
2040	$294,622	$368,277	$(73,655)	$(19,034)
2041	$294,622	$368,277	$(73,655)	$(17,789)
2042	$294,622	$368,277	$(73,655)	$(16,625)
2043	$294,622	$368,277	$(73,655)	$(15,537)
2044	$294,622	$368,277	$(73,655)	$(14,521)
2045	$294,622	$368,277	$(73,655)	$(13,571)
2046	$147,311	$184,139	$(36,828)	$(178,061)
Total	$5,892,437	$6,984,302	$(1,091,864)	$(356,123)

Source: CDOT, Muller Engineering, AECOM

Table 4-4 Additional Transit Operations Costs – CO119 Project (2026-2046)

Year	Additional Transit Services	Additional Transit Operating Hours (Daily)	Additional Transit Operating Hours (Annual)	Additional Transit Operating Cost (Annual)	Additional Transit Operating Cost (Discounted)
2025	7	37	4,853	$514,453	$342,802
2026	7	37	9,707	$1,028,907	$685,604
2027	8	43	11,093	$1,175,893	$732,287
2028	8	43	11,093	$1,175,893	$684,381
2029	9	48	12,480	$1,322,880	$719,559
2030	9	48	12,480	$1,322,880	$672,485
2031	9	48	12,480	$1,322,880	$628,491
2032	9	48	12,480	$1,322,880	$587,375
2033	9	48	12,480	$1,322,880	$548,948
2034	9	48	12,480	$1,322,880	$513,036
2035	9	48	12,480	$1,322,880	$479,473
2036	9	48	12,480	$1,322,880	$448,105
2037	9	48	12,480	$1,322,880	$418,790
2038	9	48	12,480	$1,322,880	$391,392
2039	9	48	12,480	$1,322,880	$365,787
2040	9	48	12,480	$1,322,880	$341,857
2041	9	48	12,480	$1,322,880	$319,493
2042	9	48	12,480	$1,322,880	$298,591
2043	9	48	12,480	$1,322,880	$279,057
2044	9	48	12,480	$1,322,880	$260,801
2045	9	48	12,480	$1,322,880	$243,740
2046	9	48	6,240	$661,440	$113,897
TOTAL			**245,440**	**$26,163,627**	**$9,161,443**

Source: RTD, Muller Engineering, AECOM

4.3. Residual Value

Many elements of the CO119 Project will have a useful life beyond 20 years and will therefore have a residual value at the end of the assessment period. Specifically, direct construction costs on the new infrastructure components of the Project which will have a residual value have a capital cost of $46.9 million in real $2020, or $56.6 million in $YOE. With a residual value of $29 million at the end of the assessment period in 2046, the discounted value of this amount at 7% is $5.0 million.

An overview of the residual value of the CO119 Project at the conclusion of the assessment period is shown in Table 4-5.

Table 4-5 Residual Value of New Infrastructure

Construction Element	Cost ($M2020)	Cost ($M-YOE)	Asset Life	Remaining Asset Life	Remaining Asset Value	Discounted to $2020
Structures (Bridges, Underpasses, Walls)	$15.2	$18.3	75	55	$13.45	$2.32
Concrete Structures (non-bridge), Concrete Surfacing and Concrete Curbing	$5.1	$6.2	50	30	$3.72	$0.64
Asphalt	$15.9	$19.2	30	10	$6.41	$1.10
Signal Systems, Electrical/Power Systems, and Signage	$7.3	$8.9	30	10	$2.95	$0.51
Drainage	$3.4	$4.1	50	30	$2.46	$0.42
Total						$4.99

5. Benefit Cost Analysis Results

Over the 20-year assessment period, the CO119 Project generates $126.2 million in benefits at a 7% discount rate and has **a BCR of 1.4:1.**

A more granular overview of the project benefit generated at 7% discount rate is shown in Table 5-1.

Table 5-1 Summary of Project Benefits and Costs – CO119 Project – Discounted at 7%

CO 119 Diagonal Highway Mobility Improvements Project	
Benefit	**$M (2020)**
Economic	
Travel Time Savings - Autos	$59.8
Travel Time Savings - Commercial Truck	$2.0
Travel Time Savings - Transit	$10.2
Operating Cost Savings - Commercial Truck	$2.8
Operating Cost (Additional) - Transit Bus Service	-$9.2
Fuel Savings - Autos	$3.4
Environmental	
Reduced Emissions - Automobiles	$0.8
Reduced Emissions - Commercial Truck	$0.2
State of Good Repair	
Net increase in O&M	-$0.4
Residual	$5.0
Safety	
Reduced Accidents	$51.7
Total Benefits	**$126.2**
Costs	
Capital Costs	$89.7
Total Costs	**$89.7**
Benefit Cost Analysis	
Net Present Value ($M)	**36.5**
Benefit Cost Ratio	**1.41**

Source: AECOM

The largest components of the benefits generated by the Project are concentrated in vehicle time savings, safety, and residual value. The vehicle time savings are driven by an overall decrease in VHT reflective of greater efficiency in travel for all modes of vehicular travel. A significant decrease in the occurrence of accidents, injuries and fatalities is reflective of the more than a dozen improvements along the corridor, generating a substantial aggregate safety benefit, which is aligned to the BUILD program mandate. There is a modest decrease in emissions associated with lower VHT over the assessment period.

The following sections includes highlights on each component of the BCA Benefits.

5.1. Safety

The implementation of the CO119 Project will realize significant reductions in accidents for all users of the Project corridor. Safety benefits are summarized in Table 5-2.

Table 5-2 Total Safety Benefits – CO119 Project

Year	Safety Benefit ($M 2020)	Safety Benefit (Discounted $M)
2026	$ 6.5	$ 4.4
2027	$ 6.6	$ 4.1
2028	$ 6.7	$ 3.9
2029	$ 6.7	$ 3.7
2030	$ 6.8	$ 3.5
2031	$ 6.9	$ 3.3
2032	$ 6.9	$ 3.1
2033	$ 7.0	$ 2.9
2034	$ 7.1	$ 2.7
2035	$ 7.1	$ 2.6
2036	$ 7.2	$ 2.4
2037	$ 7.3	$ 2.3
2038	$ 7.3	$ 2.2
2039	$ 7.4	$ 2.1
2040	$ 7.5	$ 1.9
2041	$ 7.5	$ 1.8
2042	$ 7.6	$ 1.7
2043	$ 7.7	$ 1.6
2044	$ 7.8	$ 1.5
2045	$ 7.8	$ 1.4
2046	$ 7.9	$ 1.4
Total	$ 144.4	$ 51.7

Source: Muller Engineering, FHWA, AECOM

The total reduction in fatalities, injuries, and PDO crashes over the 20-year period of analysis is valued as $51.7 million, discounted at 7 percent.

5.2. State of Good Repair

Many elements of the CO119 Project will have a useful life beyond 20 years and will therefore have a residual value at the end of the assessment period. Specifically, direct construction costs on the new infrastructure components of the Project which will have a residual value have a capital cost of $46.9 million in real $2020, or $56.6 million in $YOE. With a residual value of $29 million at the end of the assessment period in 2046, the discounted value of this amount at 7% is $5.0 million.

An overview of the residual value of the CO119 Project at the conclusion of the assessment period is shown in Table 4-5.

Table 5-3 Residual Value of New Infrastructure – CO119 Project

Construction Element	Cost ($M2020)	Cost ($M-YOE)	Asset Life	Remaining Asset Life	Remaining Asset Value	Discounted to $2020
Structures (Bridges, Underpasses, Walls)	$15.2	$18.3	75	55	$13.45	$2.32
Concrete Structures (non-bridge), Concrete Surfacing and Concrete Curbing	$5.1	$6.2	50	30	$3.72	$0.64
Asphalt	$15.9	$19.2	30	10	$6.41	$1.10
Signal Systems, Electrical/Power Systems, and Signage	$7.3	$8.9	30	10	$2.95	$0.51
Drainage	$3.4	$4.1	50	30	$2.46	$0.42
Total						$4.99

Source: BEA, AECOM

5.3. Economic Competitiveness

5.3.1. Personal Vehicles and Passengers Travel Time Savings

The main benefit observed under this BCA is the travel time savings resulted from modelled changes in the efficiency of the corridor as a result of the implementation of the Project. Over the 20-year assessment period, travel time savings incurred by automobile drivers and their passengers totaled approximately 10.8 million hours, equating to undiscounted travel time savings of $193 million in constant $2020. When discounted at 7% to the base assessment year, total travel time savings for automobile drivers and their passengers totaled $59.8 million.

5.3.2. Commercial Drivers Travel Time Savings

Over the 20-year assessment period, travel time savings incurred by commercial drivers totaled approximately 203,000 hours, equating to undiscounted travel time savings of $6.5 million in constant $2020. When discounted at 7% to the base assessment year, total travel time savings for commercial drivers totaled $2 million.

5.3.3. Transit Passenger Travel Time Savings

Over the 20-year assessment period, travel time savings incurred by transit passengers totaled approximately 1.7 million hours, equating to undiscounted travel time savings of $30 million in constant $2020. When discounted at 7% to the base assessment year, total travel time savings for transit passengers totaled $10.2 million.

5.3.4. Vehicle Operating Costs Savings – Commercial Drivers

Over the 20-year assessment period, travel time savings incurred by commercial drivers totaled approximately 203,000 hours, equating to undiscounted operating costs savings of $8.9 million in constant $2020. When discounted at 7% to the base assessment year, total operating costs savings for commercial drivers totaled $2.8 million.

5.3.5. Fuel Savings

More efficient operations along the CO119 corridor due to the implementation of the Project will lead to fuel savings for automobiles due to a reduction in VHT. An overview of the fuel savings is shown in Table 3-3.

Table 5-4 Fuel Savings - Automobiles (2026-2046)

	Fuel Savings (Gallons)	Fuel Savings - (2022$)	Discounted Fuel Savings (7%)
Automobiles	2,570,480	$10,934,824	$3,383,123

Source: ATRI (2021), AECOM

5.4. Environmental Sustainability

5.4.1. Emission Reductions

The overall increase in emissions for personal vehicles and commercial trucks was calculated through the evaluation of the decrease in vehicle hours travelled across the corridor over the assessment period. These changes in VHT for automobiles and commercial trucks resulted in an overall benefit of $0.8 million and $0.2 million, respectively, at a 7% discount rate. A summary of the valuation of the emissions avoided by a decrease in vehicle hours travelled across the assessment period is shown in Table 5-5.

Table 5-5 Valuation of Emissions Avoided – CO119 Project (2026-2046)

Pollutant	$2020	Discounted at 7%
	Auto	Truck
VOC	Not Valued	Not Valued
Nox	$ 445,852	$ 138,988
PM2.5	$ 393,113	$ 367,240
PM10	Not Valued	Not Valued
CO2	$ 1,583,405	$ 128,960
Total	$ 2,422,369	$ 635,188
Discounted	**$ 762,999**	**$ 202,502**

Source: APEX Design, EPA, USDOT, AECOM