MEMORANDUM

To: City of Hendersonville, NC

From: Alta Planning + Design

Date: 01/13/2025

Re: Hendersonville, NC Above the Mud BUILD Grant: Benefit-Cost Analysis Summary Memo

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Benefit-Cost Analysis for Hendersonville, NC Above the Mud BUILD Grant Application: All Components

Introduction

This Benefit-Cost Analysis (BCA) includes the benefits and costs for the proposed project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years (3 years of planning, engineering and construction and 20 years of operation) and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 dollars.

Each component of the project was assessed in separate BCA following the principles documented in the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs as of November 2024.

The following categories of benefits were considered in the BCA:

- **Safety:** The expected reduction in collisions and associated costs.
- **Environmental Sustainability:** Includes reductions in the following pollutants that impact air quality, CO_2, NO_X SO_2, and $PM_{2.5}$.
- **Quality of Life:** The expected reduction in mortality rates due to increased physical activity from new users of the project.
- **Economic Competitiveness:** Includes savings in household transportation costs and traffic congestion costs.
- **State of Good Repair:** Includes reductions in roadway maintenance costs.
- **Maintenance costs (dis-benefit):** Covers the ongoing costs of upkeep to the proposed project.

Results Summary

Table 1 displays the total benefits by category included in the BCA. The capital costs included in all the BCA are $18.2 million. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2049) and at a 3.1 percent real discount rate will have a net present value of **$12.1 million** and a benefit-cost ratio of **1.67 : 1.0.** This is summarized in Table 2.[1]

Table 1. Total Undiscounted Benefits over 20 years of Operation

CATEGORY	1. Above the Mud Greenway and 4. Oklawaha Greenway Improvements	2. 7th Avenue Improvements	3. Festival Street / South Main Street Improvements	Hendersonville, NC Above the Mud BUILD Grant All Components
	Monetary Value (2023 dollars)	Monetary Value (2023 dollars)	Monetary Value (2023 dollars)	Monetary Value (2023 dollars)
Safety Benefits	$3,200,000	$19,300,000	$6,780,000	$29,280,000
Environmental Sustainability	$54,900	$3,600	$11,700	$70,200
Quality of Life	$9,423,000	$767,000	$4,931,000	$15,121,000
Economic Competitiveness	$201,300	$13,000	$43,700	$258,000
State of Good Repair	$29,900	$2,000	$6,400	$38,300
Maintenance Costs (Dis-benefit)	($600,000)	($100,000)	($1,000,000)	($1,700,000)
Residual Value	$2,100,000	$2,067,000	$2,670,000	$6,837,000
TOTAL BENEFITS (UNDISCOUNTED)	$14,409,000	$22,053,000	$13,430,000	$49,892,000

[1] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Table 2. Benefit-Cost Analysis Summary

CATEGORY	1. Above the Mud Greenway and 4. Oklawaha Greenway Improvements	2. 7th Avenue Improvements	3. Festival Street / South Main Street Improvements	Hendersonville, NC Above the Mud BUILD Grant All Components
	Monetary Value (2023 dollars)	Monetary Value (2023 dollars)	Monetary Value (2023 dollars)	Monetary Value (2023 dollars)
Net Discounted Benefits	$8,683,000	$13,602,000	$8,009,000	$30,294,000
Net Discounted Capital Costs	($5,604,000)	($5,489,000)	($7,082,000)	($18,175,000)
Net Present Value	$3,078,000	$8,113,000	$927,000	$12,118,000
Benefit - Cost Ratio	1.55:1	2.48:1	1.13:1	1.67 : 1

Table 3. Summarized GHG and Criteria Pollutants

METRIC TONS OF GHGS AND CRITERIA POLLUTANTS	1. Above the Mud Greenway and 4. Oklawaha Greenway Improvements	2. 7th Avenue Improvements	3. Festival Street / South Main Street Improvements	Hendersonville, NC Above the Mud BUILD Grant All Components
PARTICUIATE MATTER 2.5 (PM 2.5) REDUCED	0.021	0.021	0.021	0.063
NITROUS OXIDES (NOx) REDUCED	2.140	2.178	2.220	6.538
SULFUR OXIDES (SOx) REDUCED	0.020	0.020	0.021	0.061
CARBON DIOXIDE REDUCED	148.141	9.425	32.116	189.682

Additional details can be found in the individual BCA Memos and spreadsheets: Greenway, 7th Avenue, Festival Street, included in the grant application package.

MEMORANDUM

To: City of Hendersonville, NC

From: Alta Planning + Design

Date: 01/23/2025

Re: BUILD Benefit-Cost Analysis Technical Memo: Components 1 and 4: Above the Mud and Oklawaha Greenway

Benefit-Cost Analysis for Hendersonville, NC Above the Mud BUILD Grant Application: Components 1 and 4: Above the Mud and Oklawaha Greenway

Executive Summary

This Benefit-Cost Analysis (BCA) includes the benefits and costs for the proposed project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years (3 years of planning, engineering and construction and 20 years of operation) and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 dollars.

The following categories of benefits were considered in the BCA:

- **Safety:** The expected reduction in collisions and associated costs.
- **Environmental Sustainability:** Includes reductions in the following pollutants that impact air quality, CO_2, NO_X SO_2, and $PM_{2.5}$.
- **Quality of Life:** The expected reduction in mortality rates due to increased physical activity from new users of the project.
- **Economic Competitiveness:** Includes savings in household transportation costs and traffic congestion costs.
- **State of Good Repair:** Includes reductions in roadway maintenance costs.
- **Maintenance costs (dis-benefit):** Covers the ongoing costs of upkeep to the proposed project.

Results Summary

Table 1 displays the total benefits by category included in the BCA. The capital costs included in the BCA are $6.62 million. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2049) and at a 3.1 percent real discount rate will have a net present value of **$3.1 million** and a benefit-cost ratio of **1.55 : 1.0.** This is summarized in Table 2.[1]

[1] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Table 1:Total Undiscounted Benefits over 20 years of Operation

CATEGORY	MONETARY VALUE (In 2023 dollars)
Safety Benefits	$ 3,200,000
Environmental Sustainability	$ 54,900
Quality of Life	$ 9,423,000
Economic Competitiveness	$ 201,300
State of Good Repair	$ 29,900
Maintenance Costs (Dis-benefit)	$ (600,000)
Residual Value	$ 2,100,000
TOTAL BENEFITS (UNDISCOUNTED)	$ 14,409,000

Table 2: Benefit-Cost Analysis Summary

CATEGORY	DISCOUNTED [2] VALUE (in 2023 dollars)
Net Discounted Benefits	$ 8,683,000
Net Discounted Capital Costs	$ (5,604,000)
Net Present Value	$ 3,078,000
Benefit - Cost Ratio	1.55:1

[2] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Background

The benefit-cost analysis (BCA) for this project follows the principles documented in the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs as of November 2024 (hereafter referred to as "USDOT BCA Guidance") and uses the recommended parameter values where applicable. The BCA includes the benefits and costs for the project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 base year dollars. Benefits and cost streams were discounted using a 3.1% per year discount rate, with the exception of carbon benefits which were discounted at 2% per year. This memo contains a detailed explanation of the BCA methodology and the parameter values that were used.

Approach to Benefits and Study Area

This BCA approach expands on the methods suggested by the National Cooperative Highway Research Program (NCHRP) Report 552: Guidelines for Analysis of Investments in Bicycle Facilities by incorporating detailed local demographic information and using new data and research that has become available since Guidelines for Analysis was published in 2006.

While construction of the project will benefit all residents of and visitors to the region, those living within three miles (about a 15-minute bike ride) and one-half mile (about a 10-minute walk) of the project will have the most convenient access and will gain the most from its completion. Accordingly, this BCA focuses on the bicycling benefits attributed to residents living within three miles of the project and on the walking benefits attributed to residents living within one-half mile project. There are several benefit categories that benefit the region more widely (reduced roadway maintenance, healthcare costs), but these ranges are used to constrain this analysis to the main beneficiaries.

Benefits were primarily calculated by comparing walking and biking activity (including crashes) under the Baseline to a Build scenario in which the project has been implemented. The baseline and build scenarios encompass an identical geography (census block groups within three (3) miles of the project). **The benefits included in the Net Present Value and Benefit-Cost Ratio calculations are the net difference between the two scenarios.** The proposed improvements and expected benefits are summarized in Table 3.

Table 3: Summary Matrix

Baseline	Build Scenario	Type of Impacts
No current connection to nearby regional Ecusta Trail being installed south of Hendersonville, NC (fully funded, partially constructed); Existing Oklawaha Greenway is closed approximately 100 days of the year due to flooding.	Construction of the Above the Mud greenway and improvements to existing Oklawaha Greenway to connect Hendersonville, NC to near-term regional Ecusta Trail and improve community connectivity.	Increase in walking within 0.5 miles of the study area and biking within 3 miles of the study area due to increased feelings of safety and comfort with a separated off-road facility. Reduced mortality benefits, reduced collisions, reduced roadway maintenance, reduced traffic congestion, and reduced household transportation costs within 3 miles of the study area.

Capital Costs

Refer to the main application for a detailed breakdown of project costs. The capital cost schedule is shown in Table 4**.** This schedule includes design, engineering, permitting, contracting and installation. The official cost estimate for this project was established with a construction sub-total of 2024, so this was deflated to the baseline year of 2023 using the November 2024 Consumer Price Index of 2.7%.

Table 4: Project Construction Schedule and Cost

Design / Construction Year	Anticipated Cost (in $2023)
2026	$ 1,580,000
2027	$ 3,170,000
2028	$ 1,580,000
Total Capital Costs	$ 6,330,000

The estimated total annual maintenance costs are $30,000 per year (undiscounted) and they were included as a disbenefit in the benefit-cost ratio. The basis for this annual cost stems from other recent southeast greenway maintenance cost estimates, primarily for activities such as mowing grass and clearing vegetation, surface clearing of the greenway, keeping greenway and the sides clear of trash and more. An additional cost is estimated due to the proximity of the greenway to Mud Creek, and extra clean-up required after major flooding events. It is considered on the conservative side, as recent studies of basic greenway maintenance from the Rails-to-Trails Conservancy[3] indicate typical costs may be lower than this amount.

Useful Life

The expected useful life of the proposed greenway is 30 years. The window of analysis used was 23 years. A residual value of $2,100,000 (undiscounted) was claimed as a benefit in the final year of the analysis period, assuming linear depreciation.

Demand

Next, the analysis estimated the expected number of biking and walking trips that would occur on the trail system. The primary inputs to the demand analysis were counts of pedestrians and bicyclists at a location on the existing Oklawaha Greenway, which proposed project see Table 5.

The bicycle and pedestrian mode-share was determined using recent estimates of demand for the connecting Ecusta Trail which has an estimated 61% bicyclist share and 39% pedestrian share.

[3] Maintenance Practices and Costs of Rail – Trails. 2014. Accessed 01/09/2024 < https://cdn2.assets-servd.host/material-civet/production/images/documents/MaintenancePracticesandCostsofRail-Trails.pdf?dm=1620062746>.

Table 5: Trail Counts on the existing Oklawaha Greenway, City of Hendersonville, NC

Trail Counter (Location)	Month	Year	Peak 24-Hr Daily Users
Oklawaha Greenway in Berkeley Park	September	2016	247
Oklawaha Greenway across from Berkeley Ball Park	August	2023	305
Oklawaha Greenway in Berkeley Park	August	2024	192
Oklawaha Greenway at Johnson's Ditch	August	2024	175
Oklawaha Greenway at Johnson's Ditch	March	2022	315
Oklawaha Greenway at Johnson's Ditch	October	2018	119

This demand estimate stems from counts along the existing Oklawaha Greenway to which the project will connect and improve. On average, 225 people use the nearby greenway in a 24-hour period. Therefore, we assume a similar usage for the new Above the Mud greenway trail. In addition, the baseline of 225 users in a 24-hour period only applies currently along the Oklawaha for 265 days out of the year. Approximately 100 days (27%) out of the year, the greenway is closed for flooding, which this project plans to address. This will allow for an additional 62 users on the existing greenway each day when this additional greenway usefulness is added. In total, we expect 287 daily users along the existing Oklawaha and new Above the Mud greenways in Hendersonville, NC as shown in Table 6. Overall, we consider this to be a relatively conservative estimate, since we expect additional use of the Oklawaha and Above the Mud trails once they connect popular downtown Hendersonville, NC directly with the 19-mile Ecusta Trail: a regional signature trail currently under construction.

Table 6. Demand Estimate

Project Name	Length (Mi)	Estimated Daily Average of Bike Trips	Estimated Daily Average of Pedestrian Trips	Average Daily Users
Above the Mud and Oklawaha Greenway	1.3	175	112	287
Total Estimate: 287 daily users				

This project includes the total 1.3 miles of the proposed greenway. Overall, it is expected there would be an estimated 175 bicyclists per day and an estimated 112 pedestrians per day. The list of comparable facilities included data collected multiple years post-construction, so it is expected that it may take multiple years after opening for the proposed trail to reach these estimates.

Benefits

The various benefits expected to result from implementation of the project are described in this section.

Walking and Biking Activity

The BCA estimated current levels of walking and biking within the project area using American Community Survey (ACS) 2021 5-year data. Table 7 displays the existing commute to work mode share for people within walking and biking distance of the proposed project. Population and demographic forecasts from Land of Sky Regional Council at the Transportation Analysis Zone (TAZ) level were used to estimate population growth in the study area over the analysis period. Actual population data from 2015 and forecasts for 2045 were collected and were interpolated for each intermediate year in the analysis.

Table 7: Means of Transportation to Work of People Living in the Study Area (2021 American Community Survey)

Corridor	Employed Population	Drove Alone	Carpool	Public Transit	Bicycled	Walked	Worked from Home	Other
Walkshed (within one-half-mile)	5,579	4,027	932	53	0	166	383	18
Bikeshed (within 3 miles)	27,761	21,827	2,837	54	16	363	2,188	462

The means of transportation to work data was converted to daily estimates and extrapolated to annual trip volumes and broken into different trip types (i.e. commute, school, college, and utilitarian) using the existing travel patterns (Table 8) and data from the National Household Transportation Survey. The annual extrapolations account for the expected number of trips per week by trip type (i.e., commute, school, and college trips are expected five out of seven days a week, and other trip types are expected to occur seven days a week).

Table 8: Trip Purpose Multiplier[4]

	Bike	Walk
Utilitarian Trip Multiplier	5.33	8.77

[4] Travel Day Person Trips (in millions), NHTSA 2017 https://nhts.ornl.gov/

Increase in Walking and Biking Activity

The Baseline scenario assumes that the walking and biking mode share will remain constant and that trips will increase annually with expected population growth. In the Build scenario, the demand estimates for the proposed project were added to the existing walking and biking activity starting in 2029 (the expected opening year). The demand estimates were escalated by the expected population growth factor each year.

Decrease in Motor Vehicle Trips

Some of the estimated annual bicycle and pedestrian trips within the proposed project area are expected to replace motor vehicle trips. Calibrated to modal shift factors reported in literature[5], a univariate regression model estimates the motor vehicle trip replacement factor based on the percentage of trips less than four miles that terminate in census block groups within three miles (approximate bicycling distance) of the proposed facility. Trip distance data is provided by Replica for a typical travel in the Hendersonville region on a Thursday in Spring 2024[6]. More details on Replica are included in Appendix A. The motor vehicle trip replacement factor for the proposed project is 0.0876. Additional details on the methodology are included in Appendix B.

To estimate the number of vehicle-miles that might be replaced by bicycling and walking trips, Table 9 shows the average trip distance of bicycling and walking trips by trip purpose. The number of vehicle miles reduced due to bicycle and pedestrian trips was calculated by multiplying the number of biking or walking trips by the trip replacement and trip distance factors. The estimated reduction in vehicle miles traveled is shown in Table 16.

Table 9: Average Trip Distance (miles)

	Bike	Walk
Commute Trips[7]	2.47	0.72
College Trips[8]	1.31	0.43
K-12 School Trips[9]	1.36	0.69
Utilitarian Trips[10]	2.28	0.83

[5] Volker et al (2019). Quantifying Reductions in Vehicle Miles Traveled from New Bike Paths, Lanes, and Cycle Tracks
[6] Replica Places (2019). https://replicahq.com/
[7] NHTS (2017). http://nhts.ornl.gov/tables09/fatcat/2009/aptl_TRPTRANS_WHYTRP1S.html
[8] Ibid.
[9] Safe Routes National Center for Safe Routes to School, Trends in Walking and Bicycling to School from 2007 to 2013 (2015).
[10] NHTS (2017). http://nhts.ornl.gov/tables09/fatcat/2009/aptl_TRPTRANS_WHYTRP1S.html

Environmental Sustainability Benefits

For every vehicle-mile reduced, there is an assumed decrease in greenhouse gases and criteria pollutants. Table 10 lists the reduction in greenhouse gases and criteria pollutants by vehicle-mile traveled. The cost to mitigate or clean-up those pollutants was calculated using the monetary values provided by the USDOT BCA Guidance Table A-6. Emission types not listed in that table were not included in the analysis. The estimated annual emission reduction benefits are shown in Table 17.

Table 10: Environmental Sustainability Multipliers

Pollutant	Value (metric tons/VMT)
Particulate Matter 2.5 ($PM_{2.5}$) [11]	0.000000008
Nitrous Oxides (NOx) [12]	0.0000008
Sulfur Oxides (SO_2) [13]	0.000000008
Carbon Dioxide[14]	0.00044

Quality of Life Benefits

More people bicycling and walking can help encourage an increase in physical activity levels, increased cardiovascular health, and other positive outcomes for users. The benefits from reduced mortality were calculated using the recommended values provided in the USDOT BCA Guidance (Table A-13) and the national distribution of age ranges and travel patterns. These benefits were only applied to the estimated number of walking and biking trips induced by the project (see Demand section). Table 11 displays the multipliers that were used. The estimated annual mortality benefits are shown in Table 18.

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[11] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[12] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[13] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[14] Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

Table 11: Mortality Reduction Multipliers

Mortality Reduction Benefits of Induced Active Transportation	Value
Walking Value per Induced Trip	$8.06
Cycling Value per Induced Trips	$7.18
Walking Age Proportion (20-74 years old)	68%
Cycling Age Proportion (20-64 years old)	59%
Trips induced from non-active modes	89%

Economic Competitiveness Benefits

For every vehicle-mile reduced, there is a reduction in household transportation costs and congestion costs. Table 12 displays the multipliers use to calculate economic competitiveness benefit. The estimated annual economic competitiveness benefits are shown in Table 19.

Table 12: Economic Competitiveness Multipliers

Type of Savings	Value
Household Transportation Cost Savings	$0.43 per VMT[15]
Congestion Cost Savings	$0.06 per VMT[16,17]

Safety Benefits

The proposed project would decrease conflicts between people walking and biking with motor vehicles. Collision data covering a five-year period (2019-2024) was provided by the North Carolina Department of Transportation. Collisions under consideration were located within a half-mile of the proposed project, where it would be expected that people walking and biking would use the proposed project facilities when implemented (Table 13).

[15] Our Driving Costs, AAA (2016).
[16] Crashes vs. Congestion: What's the Cost to Society? AAA (2011). https://exchange.aaa.com/wp-content/uploads/2012/07/AAA-Crashes-vs-Congestion-2011.pdf
[17] Crashes vs. Congestion: What's the Cost to Society? AAA (2011). https://exchange.aaa.com/wp-content/uploads/2012/07/AAA-Crashes-vs-Congestion-2011.pdf

Different Crash Reduction Factors were applied to the selected crashes for each segment of the project and the benefits were monetized using the values provided in the USDOT BCA Guidance Appendix A, Table A-1 for KABCO Level data. The CRFs used were Install Shared Use Path (CM ID 9250, CRF 0.25) for nearby bicycle crashes and Install Sidewalk (CM ID 11246, CRF 0.402) for pedestrian crashes. The estimated annual safety benefits are shown in Table 20.

Table 13: Summary of Collisions

Project	Total Number of Collisions (2019-2024)	Fatal (K)	Incapacit-ating (A)	Serious (B)	Possible (C)	PDO (O)
Bicycle Collisions	4	0	0	2	2	0
Pedestrian Collisions	11	0	0	6	4	1
Average Annual Bicycle Collisions	0.7	0	0	0.35	0.35	0
Average Annual Pedestrian Collisions	1.91	0	0	1.04	0.70	0.17

State-of-good Repair Benefits

Table 14 shows the estimated roadway maintenance cost savings associated with a reduction in vehicle-miles traveled.

Table 14: State of Good Repair Multiplier

	Value (metric tons/VMT)
Roadway Maintenance Cost Savings	$0.05 per VMT[18]

[18] Kitamura, R., Zhao, H., and Gubby, A. R. Development of a Pavement Maintenance Cost Allocation Model. Institute of Transportation Studies, University of California, Davis. https://trid.trb.org/view.aspx?id=261768

Results

Table 15 through Table 24 display the results of the benefit-cost analysis for each year of the analysis period. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2048) and at a 3.1 percent real discount rate (2.0 percent for carbon) will have a net present value of **$3.1 million** and a benefit-cost ratio of **1.55 : 1.0.**

Table 15: Estimated Annual Bicycle and Walk Trips

Year	Baseline	Build Scenario	Additional Trips
2026	1,265,800	1,265,800	-
2027	1,266,400	1,266,400	-
2028	1,267,100	1,267,100	-
2029	1,267,700	1,365,200	97,500
2030	1,268,300	1,367,200	98,900
2031	1,268,900	1,369,300	100,400
2032	1,269,600	1,371,300	101,700
2033	1,270,200	1,373,400	103,200
2034	1,270,800	1,375,500	104,700
2035	1,271,400	1,377,600	106,200
2036	1,272,100	1,379,800	107,700
2037	1,272,700	1,381,900	109,200
2038	1,273,300	1,384,100	110,800
2039	1,273,900	1,386,300	112,400
2040	1,274,600	1,388,600	114,000
2041	1,275,200	1,390,800	115,600
2042	1,275,800	1,393,100	117,300
2043	1,276,400	1,395,400	119,000
2044	1,277,100	1,397,700	120,600
2045	1,277,700	1,400,100	122,400
2046	1,278,300	1,402,500	124,200
2047	1,278,900	1,404,900	126,000
2048	1,279,600	1,407,300	127,700
Total Additional Trips:		2,239,500	

Table 16: Estimated Annual Vehicle Miles Reduced

Year	Baseline	Build Scenario	Additional Vehicle Miles Reduced
2026	99,800	99,800	-
2027	99,900	99,900	-
2028	99,900	99,900	-
2029	100,000	114,500	14,500
2030	100,000	114,700	14,700
2031	100,100	115,000	14,900
2032	100,100	115,200	15,100
2033	100,200	115,500	15,300
2034	100,200	115,800	15,600
2035	100,300	116,100	15,800
2036	100,300	116,300	16,000
2037	100,400	116,600	16,200
2038	100,400	116,900	16,500
2039	100,500	117,200	16,700
2040	100,500	117,500	17,000
2041	100,600	117,800	17,200
2042	100,600	118,100	17,500
2043	100,700	118,300	17,600
2044	100,700	118,700	18,000
2045	100,800	119,000	18,200
2046	100,800	119,300	18,500
2047	100,900	119,600	18,700
2048	100,900	119,900	19,000
Total Additional Vehicle Miles Reduced:		333,000	

Table 17: Estimated Annual Environmental Sustainability Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$14,400	$16,500	$2,100
2030	$14,700	$16,900	$2,200
2031	$14,900	$17,200	$2,300
2032	$15,100	$17,400	$2,300
2033	$15,300	$17,700	$2,400
2034	$15,500	$17,900	$2,400
2035	$15,700	$18,200	$2,500
2036	$15,900	$18,400	$2,500
2037	$16,100	$18,700	$2,600
2038	$16,300	$19,000	$2,700
2039	$16,500	$19,200	$2,700
2040	$16,700	$19,500	$2,800
2041	$16,900	$19,800	$2,900
2042	$17,100	$20,100	$3,000
2043	$17,400	$20,400	$3,000
2044	$17,600	$20,700	$3,100
2045	$17,800	$21,000	$3,200
2046	$18,000	$21,300	$3,300
2047	$18,300	$21,700	$3,400
2048	$18,500	$22,000	$3,500
Total Benefits:			$54,900

Table 18: Estimated Annual Quality of Life Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$6,102,000	$6,512,000	$410,000
2030	$6,105,000	$6,521,000	$416,000
2031	$6,108,000	$6,530,000	$422,000
2032	$6,111,000	$6,539,000	$428,000
2033	$6,114,000	$6,548,000	$434,000
2034	$6,117,000	$6,557,000	$440,000
2035	$6,120,000	$6,567,000	$447,000
2036	$6,123,000	$6,576,000	$453,000
2037	$6,126,000	$6,586,000	$460,000
2038	$6,129,000	$6,595,000	$466,000
2039	$6,132,000	$6,605,000	$473,000
2040	$6,135,000	$6,615,000	$480,000
2041	$6,138,000	$6,625,000	$487,000
2042	$6,141,000	$6,635,000	$494,000
2043	$6,144,000	$6,645,000	$501,000
2044	$6,147,000	$6,655,000	$508,000
2045	$6,150,000	$6,665,000	$515,000
2046	$6,153,000	$6,675,000	$522,000
2047	$6,156,000	$6,686,000	$530,000
2048	6,159,000	6,696,000	$537,000
Total Benefits:			$9,423,000

Table 19: Estimated Annual Economic Competitiveness Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$60,400	$69,200	$8,800
2030	$60,400	$69,300	$8,900
2031	$60,500	$69,500	$9,000
2032	$60,500	$69,600	$9,100
2033	$60,500	$69,800	$9,300
2034	$60,500	$70,000	$9,500
2035	$60,600	$70,100	$9,500
2036	$60,600	$70,300	$9,700
2037	$60,600	$70,500	$9,900
2038	$60,700	$70,600	$9,900
2039	$60,700	$70,800	$10,100
2040	$60,700	$71,000	$10,300
2041	$60,800	$71,100	$10,300
2042	$60,800	$71,300	$10,500
2043	$60,800	$71,500	$10,700
2044	$60,800	$71,700	$10,900
2045	$60,900	$71,900	$11,000
2046	$60,900	$72,100	$11,200
2047	$60,900	$72,200	$11,300
2048	$61,000	$72,400	$11,400
Total Benefits:			$201,300

Table 20: Estimated Annual Safety Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$-	$160,000	$160,000
2030	$-	$160,000	$160,000
2031	$-	$160,000	$160,000
2032	$-	$160,000	$160,000
2033	$-	$160,000	$160,000
2034	$-	$160,000	$160,000
2035	$-	$160,000	$160,000
2036	$-	$160,000	$160,000
2037	$-	$160,000	$160,000
2038	$-	$160,000	$160,000
2039	$-	$160,000	$160,000
2040	$-	$160,000	$160,000
2041	$-	$160,000	$160,000
2042	$-	$160,000	$160,000
2043	$-	$160,000	$160,000
2044	$-	$160,000	$160,000
2045	$-	$160,000	$160,000
2046	$-	$160,000	$160,000
2047	$-	$160,000	$160,000
2048	$-	$160,000	$160,000
Total Benefits:			$3,200,000

Table 21: Estimated Annual State of Good Repair Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$9,000	$10,300	$1,300
2030	$9,000	$10,300	$1,300
2031	$9,000	$10,300	$1,300
2032	$9,000	$10,400	$1,400
2033	$9,000	$10,400	$1,400
2034	$9,000	$10,400	$1,400
2035	$9,000	$10,400	$1,400
2036	$9,000	$10,500	$1,500
2037	$9,000	$10,500	$1,500
2038	$9,000	$10,500	$1,500
2039	$9,000	$10,500	$1,500
2040	$9,000	$10,600	$1,600
2041	$9,100	$10,600	$1,500
2042	$9,100	$10,600	$1,500
2043	$9,100	$10,700	$1,600
2044	$9,100	$10,700	$1,600
2045	$9,100	$10,700	$1,600
2046	$9,100	$10,700	$1,600
2047	$9,100	$10,800	$1,700
2048	$9,100	$10,800	$1,700
Total Benefits:			$29,900

Table 22: Estimated Annual Maintenance Disbenefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$-	$(30,000)	$(30,000)
2030	$-	$(30,000)	$(30,000)
2031	$-	$(30,000)	$(30,000)
2032	$-	$(30,000)	$(30,000)
2033	$-	$(30,000)	$(30,000)
2034	$-	$(30,000)	$(30,000)
2035	$-	$(30,000)	$(30,000)
2036	$-	$(30,000)	$(30,000)
2037	$-	$(30,000)	$(30,000)
2038	$-	$(30,000)	$(30,000)
2039	$-	$(30,000)	$(30,000)
2040	$-	$(30,000)	$(30,000)
2041	$-	$(30,000)	$(30,000)
2042	$-	$(30,000)	$(30,000)
2043	$-	$(30,000)	$(30,000)
2044	$-	$(30,000)	$(30,000)
2045	$-	$(30,000)	$(30,000)
2046	$-	$(30,000)	$(30,000)
2047	$-	$(30,000)	$(30,000)
2048	$-	$(30,000)	$(30,000)
Total Benefits:			$(600,000)

Table 23: Estimated Annual Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$6,186,000	$6,738,000	$552,000
2030	$6,189,000	$6,747,000	$558,000
2031	$6,193,000	$6,757,000	$564,000
2032	$6,196,000	$6,766,000	$570,000
2033	$6,199,000	$6,776,000	$577,000
2034	$6,202,000	$6,785,000	$583,000
2035	$6,205,000	$6,795,000	$590,000
2036	$6,209,000	$6,805,000	$596,000
2037	$6,212,000	$6,815,000	$603,000
2038	$6,215,000	$6,825,000	$610,000
2039	$6,218,000	$6,835,000	$617,000
2040	$6,222,000	$6,846,000	$624,000
2041	$6,225,000	$6,856,000	$631,000
2042	$6,228,000	$6,866,000	$638,000
2043	$6,232,000	$6,877,000	$645,000
2044	$6,235,000	$6,888,000	$653,000
2045	$6,238,000	$6,898,000	$660,000
2046	$6,241,000	$6,909,000	$668,000
2047	$6,245,000	$6,921,000	$676,000
2048	$6,248,000	$9,042,000	$2,794,000
Total Benefits:			$14,409,000

Table 24: Estimated Discounted Net Costs and Benefits (carbon discounted at 2.0%, all others Discounted at 3.1%)[19]

Year	Discounted Costs	Discounted Benefits	Net Cumulative Discounted Costs and Benefits
2026	$(1,442,000)	$-	$(1,442,000)
2027	$(2,806,000)	$-	$(4,247,000)
2028	$(1,356,000)	$-	$(5,604,000)
2029	$-	$460,000	$(5,144,000)
2030	$-	$451,000	$(4,693,000)
2031	$-	$442,000	$(4,251,000)
2032	$-	$434,000	$(3,818,000)
2033	$-	$425,000	$(3,392,000)
2034	$-	$417,000	$(2,975,000)
2035	$-	$409,000	$(2,566,000)
2036	$-	$401,000	$(2,165,000)
2037	$-	$394,000	$(1,772,000)
2038	$-	$386,000	$(1,386,000)
2039	$-	$379,000	$(1,007,000)
2040	$-	$371,000	$(636,000)
2041	$-	$364,000	$(271,000)
2042	$-	$358,000	$86,000
2043	$-	$351,000	$437,000
2044	$-	$344,000	$781,000
2045	$-	$338,000	$1,119,000
2046	$-	$331,000	$1,450,000
2047	$-	$325,000	$1,775,000
2048	$-	$1,303,000	$3,078,000
Total Net Discounted Costs: $ 5,604,000		Total Discounted Net Benefits: $8,683,000	Net Present Value: $3,078,000
Benefit-Cost Ratio: 1.55:1			

[19] Carbon reduction benefits were discounted at 2%.

MEMORANDUM

To: City of Hendersonville, NC

From: Alta Planning + Design

Date: 01/13/2025

Re: BUILD Benefit-Cost Analysis Technical Memo: Component 2: 7th Avenue Complete Street Improvements

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Benefit-Cost Analysis for Hendersonville, NC Above the Mud BUILD Grant Application: Component 2: 7th Avenue Complete Street Improvements

Executive Summary

This Benefit-Cost Analysis (BCA) includes the benefits and costs for the proposed project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years (3 years of planning, engineering and construction and 20 years of operation) and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 dollars.

The following categories of benefits were considered in the BCA:

- **Safety:** The expected reduction in collisions and associated costs.
- **Environmental Sustainability:** Includes reductions in the following pollutants that impact air quality, CO_2, NO_X SO_2, and $PM_{2.5}$.
- **Quality of Life:** The expected reduction in mortality rates due to increased physical activity from new users of the project.
- **Economic Competitiveness:** Includes savings in household transportation costs and traffic congestion costs.
- **State of Good Repair:** Includes reductions in roadway maintenance costs.
- **Maintenance costs (dis-benefit):** Covers the ongoing costs of upkeep to the proposed project.

Results Summary

Table 1 displays the total benefits by category included in the BCA. The capital costs included in the BCA are $6.2 million. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2048) and at a 3.1 percent real discount rate will have a net present value of **$8.1 million** and a benefit-cost ratio of **2.48 : 1.0.** This is summarized in Table 2.[1]

[1] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Table 1:Total Undiscounted Benefits over 20 years of Operation

CATEGORY	MONETARY VALUE (In 2023 dollars)
Safety Benefits	$ 19,300,000
Environmental Sustainability	$ 3,600
Quality of Life	$ 767,000
Economic Competitiveness	$ 13,000
State of Good Repair	$ 2,000
Maintenance Costs (Dis-benefit)	$ (100,000)
Residual Value	$ 2,067,000
TOTAL BENEFITS (UNDISCOUNTED)	$ 22,053,000

Table 2: Benefit-Cost Analysis Summary

CATEGORY	DISCOUNTED [2] VALUE (in 2023 dollars)
Net Discounted Benefits	$ 13,602,000
Net Discounted Capital Costs	$ (5,489,000)
Net Present Value	$ 8,113,000
Benefit - Cost Ratio	2.48:1

[2] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Background

The benefit-cost analysis (BCA) for this project follows the principles documented in the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs as of November 2024 (hereafter referred to as "USDOT BCA Guidance") and uses the recommended parameter values where applicable. The BCA includes the benefits and costs for the project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 base year dollars. Benefits and cost streams were discounted using a 3.1% per year discount rate, with the exception of carbon benefits which were discounted at 2% per year. This memo contains a detailed explanation of the BCA methodology and the parameter values that were used.

Approach to Benefits and Study Area

This BCA approach expands on the methods suggested by the National Cooperative Highway Research Program (NCHRP) Report 552: Guidelines for Analysis of Investments in Bicycle Facilities by incorporating detailed local demographic information and using new data and research that has become available since Guidelines for Analysis was published in 2006.

While construction of the project will benefit all residents of and visitors to the region, those living within three miles (about a 15-minute bike ride) and one-half mile (about a 10-minute walk) of the project will have the most convenient access and will gain the most from its completion. Accordingly, this BCA focuses on the bicycling benefits attributed to residents living within three miles of the project and on the walking benefits attributed to residents living within one-half mile project. There are several benefit categories that benefit the region more widely (reduced roadway maintenance, healthcare costs), but these ranges are used to constrain this analysis to the main beneficiaries.

Benefits were primarily calculated by comparing walking and biking activity (including crashes) under the Baseline to a Build scenario in which the project has been implemented. The baseline and build scenarios encompass an identical geography (census block groups within three (3) miles of the project). **The benefits included in the Net Present Value and Benefit-Cost Ratio calculations are the net difference between the two scenarios.** The proposed improvements and expected benefits are summarized in Table 3.

Table 3: Summary Matrix

Baseline	Build Scenario	Type of Impacts
No current connection to nearby regional Ecusta Trail being installed south of Hendersonville, NC (fully funded, partially constructed)	Construction of street improvements on 7th Avenue to enhance connectivity of the existing Oklawaha Greenway to downtown Hendersonville, NC and through other portions of the BUILD project to near-term regional Ecusta Trail.	Increase in walking within 0.5 miles of the study area and biking within 3 miles of the study area due to increased feelings of safety and comfort with addition of sidewalk, lighting, curb extensions and crossing improvements on 7th Avenue. Reduced mortality benefits, reduced collisions, reduced roadway maintenance, reduced traffic congestion, and reduced household transportation costs within 3 miles of the study area.

Capital Costs

Refer to the main application for a detailed breakdown of project costs. The capital cost schedule is shown in Table 4**.** This schedule includes design, engineering, permitting, contracting and installation. The official cost estimate for this project was established with a construction sub-total of 2024, so this was deflated to the baseline year of 2023 using the November 2024 Consumer Price Index of 2.7%.

Table 4: Project Construction Schedule and Cost

Design/Construction Year	Anticipated Cost
2026	$1,550,000
2027	$3,100,000
2028	$1,550,000
Total Capital Costs	$6,200,000

The estimated total annual maintenance costs are $5,000 per year (undiscounted) and they were included as a disbenefit in the benefit-cost ratio. The basis for this annual cost stems from conversations with the client around current maintenance activities along the roadway.

Useful Life

The expected useful life of the street improvements is 30 years. The window of analysis used was 23 years. A residual value of $2,067,000 (undiscounted) was claimed as a benefit in the final year of the analysis period, assuming linear depreciation.

Demand

Next, the analysis estimated the expected number of biking and walking trips that would occur due to the street improvements. The primary inputs to the demand analysis were existing counts of pedestrians at a location on the existing roadway, see Table 5.

Table 5: Pedestrians on 7th Avenue, City of Hendersonville, NC

Trail Counter (Location)	Month	Year	Peak 24-Hr Daily Users
North of 7th Avenue East, near the parking lot, on a signpost, on the eastern edge of William H King Memorial Park.	August	2024	317

This demand estimate stems from counts along 7th Avenue near where the project will connect and improve. According to this count, 317 people use the nearby greenway in a 24-hour period. Therefore, we assume a similar baseline for the project corridor of 317 pedestrians each day. Examining current land uses, and based on knowledge of the study area, the project team assumed a bicycle estimate of 10% of that of existing pedestrians or 32 bicycles per day.

Our team is a aware of recent estimates developed for the Caltrans Active Transportation Benefit-Cost Tool (Fitch et al. 2022)[3] and detailed results from the following research studies: Broach et al. (2012)[4], Broach and Dill (2015, 2016, 2017)[5], McNeil et al. (2015)[6], and Sevtsuk et al. (2021)[7]; all of which indicate that pedestrian use could be expected to increase by 4% percent and bicycle use by 29% after implementation of the proposed improvements. Therefore, we expect 22 new daily users, 9 bicycles (32*0.29 = 9 bicycles) and 13 pedestrians (317*0.04 = 13 pedestrians) along 7th Avenue in Hendersonville, NC as shown in Table 6.

Table 6. Demand Estimate

Project Name	Length (Mi)	Estimated Daily Average of Bike Trips	Estimated Daily Average of Pedestrian Trips	Average Daily Users
7th Avenue Streetscape Improvements	0.4	9	13	22
Total Estimate: 22 daily additional users				

[3] Fitch, D.T., S. Kamalapuram, M. Favetti, and S.L. Handy. 2022. Caltrans Active Transportation Benefit-Cost Tool. Technical Documentation, Institute for Transportation Studies, University of California, Davis, Version 0.1.0. Last updated July 31, 2022. <https://activetravelbenefits.ucdavis.edu/Caltrans%20ATP%20BC%20Tool%20Technical%20Documentation%20Final%20Draft.pdf>.
[4] Broach, J., J. Dill, and J. Gliebe. 2012. "Where Do Cyclists Ride? A Route Choice Model Developed with Revealed Preference GPS Data." Transportation Research Part A: Policy and Practice 46(10), 1730–1740.
[5] Broach, J., and J. Dill. 2015. Pedestrian Route Choice Model Estimated from Revealed Preference GPS Data. In Transportation Research Board 94th Annual Meeting. Washington, DC.; Broach, J., and J. Dill. 2016. "Using Predicted Bicyclist and Pedestrian Route Choice to Enhance Mode Choice Models." Transportation Research Record 2564(1), 52–59. Broach, J., and J. Dill. 2017. Bridging the Gap: Using Network Connectivity and Quality Measures to Predict Bicycle Commuting. Paper presented at the 96th Annual Meeting of the Transportation Research Board.
[6] McNeil, N., C.M. Monsere, and J. Dill. 2015. "Influence of Bike Lane Buffer Types on Perceived Comfort and Safety of Bicyclists and Potential Bicyclists." Transportation Research Record 2520(1), 132–142.
[7] Sevtsuk, A., R. Basu, X. Li, and R. Kalvo. 2021. "A Big Data Approach to Understanding Pedestrian Route Choice Preferences: Evidence from San Francisco." Travel Behaviour and Society 25, 41–51. https://doi.org/10.1016/j.tbs.2021.05.010.

Benefits

The various benefits expected to result from implementation of the project are described in this section.

Walking and Biking Activity

The BCA estimated current levels of walking and biking within the project area using American Community Survey (ACS) 2021 5-year data. Table 7 displays the existing commute to work mode share for people within walking and biking distance of the proposed project. Population and demographic forecasts from Land of Sky Regional Council at the Transportation Analysis Zone (TAZ) level were used to estimate population growth in the study area over the analysis period. Actual population data from 2015 and forecasts for 2045 were collected and were interpolated for each intermediate year in the analysis.

Table 7: Means of Transportation to Work of People Living in the Study Area (2021 American Community Survey)

Corridor	Employed Population	Drove Alone	Carpool	Public Transit	Bicycled	Walked	Worked from Home	Other
Walkshed (within one-half-mile)	5,579	4,027	932	53	0	166	383	18
Bikeshed (within 3 miles)	27,761	21,827	2,837	54	16	363	2,188	462

The means of transportation to work data was converted to daily estimates and extrapolated to annual trip volumes and broken into different trip types (i.e. commute, school, college, and utilitarian) using the existing travel patterns (Table 8) and data from the National Household Transportation Survey. The annual extrapolations account for the expected number of trips per week by trip type (i.e., commute, school, and college trips are expected five out of seven days a week, and other trip types are expected to occur seven days a week).

Table 8: Trip Purpose Multiplier[8]

	Bike	Walk
Utilitarian Trip Multiplier	5.33	8.77

[8] Travel Day Person Trips (in millions), NHTSA 2017 https://nhts.ornl.gov/

Increase in Walking and Biking Activity

The Baseline scenario assumes that the walking and biking mode share will remain constant and that trips will increase annually with expected population growth. In the Build scenario, the demand estimates for the proposed project were added to the existing walking and biking activity starting in 2029 (the expected opening year). The demand estimates were escalated by the expected population growth factor each year.

Decrease in Motor Vehicle Trips

Some of the estimated annual bicycle and pedestrian trips within the proposed project area are expected to replace motor vehicle trips. Calibrated to modal shift factors reported in literature[9], a univariate regression model estimates the motor vehicle trip replacement factor based on the percentage of trips less than four miles that terminate in census block groups within three miles (approximate bicycling distance) of the proposed facility. Trip distance data is provided by Replica for a typical travel in the Hendersonville region on a Thursday in Spring 2024[10]. More details on Replica are included in Appendix A. The motor vehicle trip replacement factor for the proposed project is 0.0876. Additional details on the methodology are included in Appendix B.

To estimate the number of vehicle-miles that might be replaced by bicycling and walking trips, Table 9 shows the average trip distance of bicycling and walking trips by trip purpose. The number of vehicle miles reduced due to bicycle and pedestrian trips was calculated by multiplying the number of biking or walking trips by the trip replacement and trip distance factors. The estimated reduction in vehicle miles traveled is shown in Table 16.

Table 9: Average Trip Distance (miles)

	Bike	Walk
Commute Trips[11]	2.47	0.72
College Trips[12]	1.31	0.43
K-12 School Trips[13]	1.36	0.69
Utilitarian Trips[14]	2.28	0.83

[9] Volker et al (2019). Quantifying Reductions in Vehicle Miles Traveled from New Bike Paths, Lanes, and Cycle Tracks
[10] Replica Places (2019). https://replicahq.com/
[11] NHTS (2017). http://nhts.ornl.gov/tables09/fatcat/2009/aptl_TRPTRANS_WHYTRP1S.html
[12] Ibid.
[13] Safe Routes National Center for Safe Routes to School, Trends in Walking and Bicycling to School from 2007 to 2013 (2015).
[14] NHTS (2017). http://nhts.ornl.gov/tables09/fatcat/2009/aptl_TRPTRANS_WHYTRP1S.html

Environmental Sustainability Benefits

For every vehicle-mile reduced, there is an assumed decrease in greenhouse gases and criteria pollutants. Table 10 lists the reduction in greenhouse gases and criteria pollutants by vehicle-mile traveled. The cost to mitigate or clean-up those pollutants was calculated using the monetary values provided by the USDOT BCA Guidance Table A-6. Emission types not listed in that table were not included in the analysis. The estimated annual emission reduction benefits are shown in Table 17.

Table 10: Environmental Sustainability Multipliers

Pollutant	Value (metric tons/VMT)
Particulate Matter 2.5 ($PM_{2.5}$) [15]	0.000000008
Nitrous Oxides (NOx) [16]	0.0000008
Sulfur Oxides (SO_2) [17]	0.000000008
Carbon Dioxide[18]	0.00044

Quality of Life Benefits

More people bicycling and walking can help encourage an increase in physical activity levels, increased cardiovascular health, and other positive outcomes for users. The benefits from reduced mortality were calculated using the recommended values provided in the USDOT BCA Guidance (Table A-13) and the national distribution of age ranges and travel patterns. These benefits were only applied to the estimated number of walking and biking trips induced by the project (see Demand section). Table 11 displays the multipliers that were used. The estimated annual mortality benefits are shown in Table 18.

[15] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[16] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[17] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[18] Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

Table 11: Mortality Reduction Multipliers

Mortality Reduction Benefits of Induced Active Transportation	Value
Walking Value per Induced Trip	$8.06
Cycling Value per Induced Trips	$7.18
Walking Age Proportion (20-74 years old)	68%
Cycling Age Proportion (20-64 years old)	59%
Trips induced from non-active modes	89%

Economic Competitiveness Benefits

For every vehicle-mile reduced, there is a reduction in household transportation costs and congestion costs. Table 12 displays the multipliers use to calculate economic competitiveness benefit. The estimated annual economic competitiveness benefits are shown in Table 19.

Table 12: Economic Competitiveness Multipliers

Type of Savings	Value
Household Transportation Cost Savings	$0.43 per VMT[19]
Congestion Cost Savings	$0.06 per VMT[20,21]

[19] Our Driving Costs, AAA (2016).
[20] Crashes vs. Congestion: What's the Cost to Society? AAA (2011). https://exchange.aaa.com/wp-content/uploads/2012/07/AAA-Crashes-vs-Congestion-2011.pdf
[21] Crashes vs. Congestion: What's the Cost to Society? AAA (2011). https://exchange.aaa.com/wp-content/uploads/2012/07/AAA-Crashes-vs-Congestion-2011.pdf

Safety Benefits

The proposed project would decrease conflicts between people walking and biking with motor vehicles. Collision data covering a five-year period (January 1, 2019- September 1, 2024) was provided by the North Carolina Department of Transportation. Collisions under consideration were located along the project corridor and included all types of collisions due to the various benefits of the proposed improvements (Table 13).

A total of 23 crashes were included in the analysis, including one fatality, a crash into a fixed object at westbound approach to the bridge over Mud Creek. Different Crash Reduction Factors were applied to the selected crashes for each segment of the project and the benefits were monetized using the values provided in the USDOT BCA Guidance Appendix A, Table A-1 for KABCO Level data. Each crash was assigned to a single countermeasure. The countermeasures selected were:

- Corridor-specific traffic calming (railroad tracks to Cherry St) for injury crashes (CM ID 587, CRF 0.18); non-injury crashes (CM ID 590, CRF 0.06)
- Pedestrian countdown signals (intersection with Ashe St) for rear-end crashes (CM ID 10117, CRF 0.13)
- Systemic signing and marking improvements (intersection with Cherry St) for injury crashes (CM ID 8893, CRF 0.186); non-injury crashes (CM ID 8892, CRF 0.121)
- Install bike lanes with lane width reduction (Cherry St to bridge over Mud Creek) for all crashes (CM ID 10741, CRF 0.266)
- Improve street lighting illuminance and uniformity (in and around Oklawaha Greenway and approaches to bridge over Mud Creek) for all crashes and especially the fatality, a crash into a fixed object at westbound approach to the bridge over Mud Creek (CM ID 11027; CRF 0.38)

The estimated annual safety benefits are shown in Table 20.

Table 13: Summary of Collisions in project corridor, January 1, 2019- September 1, 2024, NCDOT

CMF	Total Collisions	Fatal (K)	Incapacit-ating (A)	Serious (B)	Possible (C)	PDO (O)	Injured – Unknown Severity (U)
Install Bike Lanes with lane reduction	6	0	0	2	0	0	4
Corridor-specific traffic calming - Injury	1	0	0	0	1	0	0
Corridor-specific traffic calming – No Injury	4	0	0	0	0	4	0
Systemic Signing and Marking - Injury	2	0	0	0	2	0	0
Systemic Signing and Marking – No Injury	6	0	0	0	0	6	0
Pedestrian Countdown Signals	2	0	0	0	0	2	0
Improve street lighting illuminance and uniformity	2	1	0	0	0	0	1
Total	23	1	0	2	3	12	5

State-of-good Repair Benefits

Table 14 shows the estimated roadway maintenance cost savings associated with a reduction in vehicle-miles traveled.

Table 14: State of Good Repair Multiplier

	Value (metric tons/VMT)
Roadway Maintenance Cost Savings	\$0.05 per VMT[22]

[22] Kitamura, R., Zhao, H., and Gubby, A. R. Development of a Pavement Maintenance Cost Allocation Model. Institute of Transportation Studies, University of California, Davis. https://trid.trb.org/view.aspx?id=261768

Results

Table 15 through Table 24 display the results of the benefit-cost analysis for each year of the analysis period. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2048) and at a 3.1 percent real discount rate (2.0 percent for carbon) will have a net present value of **$8.1 million** and a benefit-cost ratio of **2.48 : 1.0.**

Table 15: Estimated Annual Bicycle and Walk Trips

Year	Baseline	Build Scenario	Additional Trips
2026	1,265,800	1,265,800	-
2027	1,266,400	1,266,400	-
2028	1,267,100	1,267,100	-
2029	1,267,700	1,275,200	7,500
2030	1,268,300	1,275,900	7,600
2031	1,268,900	1,276,700	7,800
2032	1,269,600	1,277,400	7,800
2033	1,270,200	1,278,100	7,900
2034	1,270,800	1,278,900	8,100
2035	1,271,400	1,279,600	8,200
2036	1,272,100	1,280,300	8,200
2037	1,272,700	1,281,100	8,400
2038	1,273,300	1,281,800	8,500
2039	1,273,900	1,282,600	8,700
2040	1,274,600	1,283,300	8,700
2041	1,275,200	1,284,100	8,900
2042	1,275,800	1,284,800	9,000
2043	1,276,400	1,285,600	9,200
2044	1,277,100	1,286,300	9,200
2045	1,277,700	1,287,100	9,400
2046	1,278,300	1,287,900	9,600
2047	1,278,900	1,288,600	9,700
2048	1,279,600	1,289,400	9,800
Total Additional Trips:		172,200	

Table 16: Estimated Annual Vehicle Miles Reduced

Year	Baseline	Build Scenario	Additional Vehicle Miles Reduced
2026	86,100	86,100	-
2027	86,200	86,200	-
2028	86,200	86,200	-
2029	86,300	87,200	900
2030	86,300	87,200	900
2031	86,400	87,300	900
2032	86,400	87,400	1,000
2033	86,400	87,400	1,000
2034	86,500	87,500	1,000
2035	86,500	87,500	1,000
2036	86,600	87,600	1,000
2037	86,600	87,600	1,000
2038	86,600	87,700	1,100
2039	86,700	87,800	1,100
2040	86,700	87,800	1,100
2041	86,800	87,900	1,100
2042	86,800	87,900	1,100
2043	86,900	88,000	1,100
2044	86,900	88,000	1,100
2045	86,900	88,100	1,200
2046	87,000	88,200	1,200
2047	87,000	88,200	1,200
2048	87,100	88,300	1,200
Total Additional Vehicle Miles Reduced:		21,000	

Table 17: Estimated Annual Environmental Sustainability Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$14,400	$14,600	$200
2030	$14,700	$14,900	$200
2031	$14,900	$15,100	$200
2032	$15,100	$15,200	$100
2033	$15,300	$15,500	$200
2034	$15,500	$15,700	$200
2035	$15,700	$15,800	$100
2036	$15,900	$16,000	$100
2037	$16,100	$16,300	$200
2038	$16,300	$16,500	$200
2039	$16,500	$16,700	$200
2040	$16,700	$16,900	$200
2041	$16,900	$17,100	$200
2042	$17,100	$17,300	$200
2043	$17,400	$17,600	$200
2044	$17,600	$17,700	$100
2045	$17,800	$18,000	$200
2046	$18,000	$18,200	$200
2047	$18,300	$18,500	$200
2048	18,500	18,700	$200
Total Benefits:			$3,600

Table 18: Estimated Annual Quality of Life Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$6,102,000	$6,135,000	$33,000
2030	$6,105,000	$6,139,000	$34,000
2031	$6,108,000	$6,142,000	$34,000
2032	$6,111,000	$6,146,000	$35,000
2033	$6,114,000	$6,149,000	$35,000
2034	$6,117,000	$6,153,000	$36,000
2035	$6,120,000	$6,156,000	$36,000
2036	$6,123,000	$6,160,000	$37,000
2037	$6,126,000	$6,163,000	$37,000
2038	$6,129,000	$6,167,000	$38,000
2039	$6,132,000	$6,171,000	$39,000
2040	$6,135,000	$6,174,000	$39,000
2041	$6,138,000	$6,178,000	$40,000
2042	$6,141,000	$6,181,000	$40,000
2043	$6,144,000	$6,185,000	$41,000
2044	$6,147,000	$6,188,000	$41,000
2045	$6,150,000	$6,192,000	$42,000
2046	$6,153,000	$6,196,000	$43,000
2047	$6,156,000	$6,199,000	$43,000
2048	6,159,000	6,203,000	$44,000
Total Benefits:			$767,000

Table 19: Estimated Annual Economic Competitiveness Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$60,400	$61,000	$600
2030	$60,400	$61,000	$600
2031	$60,500	$61,000	$500
2032	$60,500	$61,100	$600
2033	$60,500	$61,100	$600
2034	$60,500	$61,100	$600
2035	$60,600	$61,200	$600
2036	$60,600	$61,200	$600
2037	$60,600	$61,300	$700
2038	$60,700	$61,300	$600
2039	$60,700	$61,300	$600
2040	$60,700	$61,400	$700
2041	$60,800	$61,400	$600
2042	$60,800	$61,500	$700
2043	$60,800	$61,500	$700
2044	$60,800	$61,500	$700
2045	$60,900	$61,600	$700
2046	$60,900	$61,600	$700
2047	$60,900	$61,700	$800
2048	$61,000	$61,700	$700
Total Benefits:			$12,900

Table 20: Estimated Annual Safety Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$-	$965,000	$965,000
2030	$-	$965,000	$965,000
2031	$-	$965,000	$965,000
2032	$-	$965,000	$965,000
2033	$-	$965,000	$965,000
2034	$-	$965,000	$965,000
2035	$-	$965,000	$965,000
2036	$-	$965,000	$965,000
2037	$-	$965,000	$965,000
2038	$-	$965,000	$965,000
2039	$-	$965,000	$965,000
2040	$-	$965,000	$965,000
2041	$-	$965,000	$965,000
2042	$-	$965,000	$965,000
2043	$-	$965,000	$965,000
2044	$-	$965,000	$965,000
2045	$-	$965,000	$965,000
2046	$-	$965,000	$965,000
2047	$-	$965,000	$965,000
2048	$-	$965,000	$965,000
Total Benefits:			$ 19,300,000

Table 21: Estimated Annual State of Good Repair Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$9,000	$9,100	$100
2030	$9,000	$9,100	$100
2031	$9,000	$9,100	$100
2032	$9,000	$9,100	$100
2033	$9,000	$9,100	$100
2034	$9,000	$9,100	$100
2035	$9,000	$9,100	$100
2036	$9,000	$9,100	$100
2037	$9,000	$9,100	$100
2038	$9,000	$9,100	$100
2039	$9,000	$9,100	$100
2040	$9,000	$9,100	$100
2041	$9,100	$9,100	$-
2042	$9,100	$9,200	$100
2043	$9,100	$9,200	$100
2044	$9,100	$9,200	$100
2045	$9,100	$9,200	$100
2046	$9,100	$9,200	$100
2047	$9,100	$9,200	$100
2048	$9,100	$9,200	$100
Total Benefits:			$1,900

Table 22: Estimated Annual Maintenance Disbenefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$-	$(5,000)	$(5,000)
2030	$-	$(5,000)	$(5,000)
2031	$-	$(5,000)	$(5,000)
2032	$-	$(5,000)	$(5,000)
2033	$-	$(5,000)	$(5,000)
2034	$-	$(5,000)	$(5,000)
2035	$-	$(5,000)	$(5,000)
2036	$-	$(5,000)	$(5,000)
2037	$-	$(5,000)	$(5,000)
2038	$-	$(5,000)	$(5,000)
2039	$-	$(5,000)	$(5,000)
2040	$-	$(5,000)	$(5,000)
2041	$-	$(5,000)	$(5,000)
2042	$-	$(5,000)	$(5,000)
2043	$-	$(5,000)	$(5,000)
2044	$-	$(5,000)	$(5,000)
2045	$-	$(5,000)	$(5,000)
2046	$-	$(5,000)	$(5,000)
2047	$-	$(5,000)	$(5,000)
2048	$-	$(5,000)	$(5,000)
Total Benefits:			$(100,000)

Table 23: Estimated Annual Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$6,186,000	$7,180,000	$994,000
2030	$6,189,000	$7,184,000	$995,000
2031	$6,193,000	$7,188,000	$995,000
2032	$6,196,000	$7,192,000	$996,000
2033	$6,199,000	$7,195,000	$996,000
2034	$6,202,000	$7,199,000	$997,000
2035	$6,205,000	$7,202,000	$997,000
2036	$6,209,000	$7,207,000	$998,000
2037	$6,212,000	$7,210,000	$998,000
2038	$6,215,000	$7,214,000	$999,000
2039	$6,218,000	$7,217,000	$999,000
2040	$6,222,000	$7,222,000	$1,000,000
2041	$6,225,000	$7,226,000	$1,001,000
2042	$6,228,000	$7,229,000	$1,001,000
2043	$6,232,000	$7,234,000	$1,002,000
2044	$6,235,000	$7,237,000	$1,002,000
2045	$6,238,000	$7,241,000	$1,003,000
2046	$6,241,000	$7,245,000	$1,004,000
2047	$6,245,000	$7,249,000	$1,004,000
2048	$6,248,000	$9,320,000	$3,072,000
Total Benefits:			$22,053,000

Table 24: Estimated Discounted Net Costs and Benefits (carbon discounted at 2.0%, all others Discounted at 3.1%)[23]

Year	Discounted Costs	Discounted Benefits	Net Cumulative Discounted Costs and Benefits
2026	$(1,414,000)	$-	$(1,414,000)
2027	$(2,744,000)	$-	$(4,158,000)
2028	$(1,331,000)	$-	$(5,489,000)
2029	$-	$828,000	$(4,661,000)
2030	$-	$803,000	$(3,857,000)
2031	$-	$780,000	$(3,078,000)
2032	$-	$757,000	$(2,321,000)
2033	$-	$734,000	$(1,587,000)
2034	$-	$712,000	$(875,000)
2035	$-	$691,000	$(183,000)
2036	$-	$671,000	$488,000
2037	$-	$651,000	$1,139,000
2038	$-	$632,000	$1,771,000
2039	$-	$613,000	$2,384,000
2040	$-	$595,000	$2,979,000
2041	$-	$578,000	$3,557,000
2042	$-	$561,000	$4,117,000
2043	$-	$544,000	$4,661,000
2044	$-	$528,000	$5,189,000
2045	$-	$512,000	$5,702,000
2046	$-	$497,000	$6,199,000
2047	$-	$483,000	$6,682,000
2048	$-	$1,432,000	$8,113,000
Total Net Discounted Costs: $ 5,489,000		Total Discounted Net Benefits: $13,602,000	Net Present Value: $8,113,000
Benefit-Cost Ratio: 2.48:1			

[23] Carbon reduction benefits were discounted at 2%.

To: City of Hendersonville, NC

From: Alta Planning + Design

Date: 01/13/2025

Re: BUILD Benefit-Cost Analysis Technical Memo: Component 3: Festival Street (South Main Street) Complete Street Improvements

Benefit-Cost Analysis for Hendersonville, NC Above the Mud BUILD Grant Application: Component 3: Festival Street/South Main Complete Street Improvements

Executive Summary

This Benefit-Cost Analysis (BCA) includes the benefits and costs for the proposed project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years (3 years of planning, engineering and construction and 20 years of operation) and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 dollars.

The following categories of benefits were considered in the BCA:

- **Safety:** The expected reduction in collisions and associated costs.
- **Environmental Sustainability:** Includes reductions in the following pollutants that impact air quality, CO_2, NO_X SO_2, and $PM_{2.5}$.
- **Quality of Life:** The expected reduction in mortality rates due to increased physical activity from new users of the project.
- **Economic Competitiveness:** Includes savings in household transportation costs and traffic congestion costs.
- **State of Good Repair:** Includes reductions in roadway maintenance costs.
- **Maintenance costs (dis-benefit):** Covers the ongoing costs of upkeep to the proposed project.

Results Summary

Table 1 displays the total benefits by category included in the BCA. The capital costs included in the BCA are $8.0 million. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2048) and at a 3.1 percent real discount rate will have a net present value of **$927,010** and a benefit-cost ratio of **1.13 : 1.0.** This is summarized in Table 2.[1]

[1] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Table 1:Total Undiscounted Benefits over 20 years of Operation

CATEGORY	MONETARY VALUE (In 2023 dollars)
Safety Benefits	$ 6,780,000
Environmental Sustainability	$ 11,700
Quality of Life	$ 4,931,000
Economic Competitiveness	$ 43,700
State of Good Repair	$ 6,400
Maintenance Costs (Dis-benefit)	$ (1,000,000)
Residual Value	$ 2,670,000
TOTAL BENEFITS (UNDISCOUNTED)	$ 13,430,000

Table 2: Benefit-Cost Analysis Summary

CATEGORY	DISCOUNTED [2] VALUE (in 2023 dollars)
Net Discounted Benefits	$ 8,009,000
Net Discounted Capital Costs	$ (7,082,000)
Net Present Value	$ 927,000
Benefit - Cost Ratio	1.13:1

[2] A 3.1% discount rate was used for all benefits and costs with the exception of carbon benefits which were discounted at 2% per year.

Background

The benefit-cost analysis (BCA) for this project follows the principles documented in the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs as of November 2024 (hereafter referred to as "USDOT BCA Guidance") and uses the recommended parameter values where applicable. The BCA includes the benefits and costs for the project that would be fully constructed if the BUILD grant is awarded. The analysis period was 23 years and assumes a useful service life of 30 years for the project. All costs and benefits are presented in 2023 base year dollars. Benefits and cost streams were discounted using a 3.1% per year discount rate, with the exception of carbon benefits which were discounted at 2% per year. This memo contains a detailed explanation of the BCA methodology and the parameter values that were used.

Approach to Benefits and Study Area

This BCA approach expands on the methods suggested by the National Cooperative Highway Research Program (NCHRP) Report 552: Guidelines for Analysis of Investments in Bicycle Facilities by incorporating detailed local demographic information and using new data and research that has become available since Guidelines for Analysis was published in 2006.

While construction of the project will benefit all residents of and visitors to the region, those living within three miles (about a 15-minute bike ride) and one-half mile (about a 10-minute walk) of the project will have the most convenient access and will gain the most from its completion. Accordingly, this BCA focuses on the bicycling benefits attributed to residents living within three miles of the project and on the walking benefits attributed to residents living within one-half mile project. There are several benefit categories that benefit the region more widely (reduced roadway maintenance, healthcare costs), but these ranges are used to constrain this analysis to the main beneficiaries.

Benefits were primarily calculated by comparing walking and biking activity (including crashes) under the Baseline to a Build scenario in which the project has been implemented. The baseline and build scenarios encompass an identical geography (census block groups within three (3) miles of the project). **The benefits included in the Net Present Value and Benefit-Cost Ratio calculations are the net difference between the two scenarios.** The proposed improvements and expected benefits are summarized in Table 3.

Table 3: Summary Matrix

Baseline	Build Scenario	Type of Impacts
No current connection to nearby regional Ecusta Trail being installed south of Hendersonville, NC (fully funded, partially constructed)	Construction of street improvements on South Main Street to enhance connectivity of downtown Hendersonville, NC and through other portions of the BUILD project to near-term regional Ecusta Trail and improving connectivity throughout downtown.	Increase in walking within 0.5 miles of the study area and biking within 3 miles of the study area due to increased feelings of safety and comfort with addition of sidewalk, lighting, signal upgrades with leading pedestrian intervals, and crossing improvements on South Main Street. Reduced mortality benefits, reduced collisions, reduced roadway maintenance, reduced traffic congestion, and reduced household transportation costs within 3 miles of the study area.

Capital Costs

Refer to the main application for a detailed breakdown of project costs. The capital cost schedule is shown in Table 4**.** This schedule includes design, engineering, permitting, contracting and installation. The official cost estimate for this project was established with a construction sub-total of 2024, so this was deflated to the baseline year of 2023 using the November 2024 Consumer Price Index of 2.7%.

Table 4: Project Construction Schedule and Cost

Design/Construction Year	Anticipated Cost
2026	$2,000,000
2027	$4,000,000
2028	$2,000,000
Total Capital Costs	$8,000,000

The estimated total annual maintenance costs are $50,000 per year (undiscounted) and they were included as a disbenefit in the benefit-cost ratio. The basis for this annual cost stems from conversations with the client around current maintenance activities along North Main Street.

Useful Life

The expected useful life of the street improvements is 30 years. The window of analysis used was 23 years. A residual value of $2,670,000 (undiscounted) was claimed as a benefit in the final year of the analysis period, assuming linear depreciation.

Demand

Next, the analysis estimated the expected number of biking and walking trips that would occur due to the street improvements. The primary inputs to the demand analysis were existing counts of pedestrians throughout several years in downtown Hendersonville, NC, see Table 5.

Table 5: Pedestrian Counts, City of Hendersonville, NC

Counter (Location)	Month	Year	Peak 24-Hr Daily Users
North Main Street between 3rd Ave and 4th Ave	May	2016	2,592
North Main Street at 5th, by Mast General Store	February	2022	1,960
Downtown Hendersonville, Main Street, between 5th Avenue and 6th Avenue, East side of the road	June	2016	2,047
South Main Street between 1st Street and Allen Street	June	2016	1,406

This demand estimate stems from counts directly north of where project will connect and improve. The average peak 24-hour users for established Complete Street portions on North Main Street is 2,200 pedestrians. Further south, just one block north of the project corridor the peak 24-hour users was approximately 30% lower, 1,406 pedestrians.

On South Main Street, where the Festival Street project will be located, land uses and transportation facilities shift to be more auto-centric. Differences between complete street environments and existing environments were approximately 30% in visitation activity according to Placer.ai data from January 1, 2023 - September 1, 2024. This is similar to the differences in average pedestrian counts in complete street environment on North Main Street. Extending this pattern of activity linearly to the project on South Main Street, the project team estimates an existing baseline daily pedestrian activity of 980 users on South Main Street / Festival Street.

Since the primary enhancement to the active transportation environment is filling a sidewalk gap, the project team assumes increase of 13% in pedestrian activity after implementation of the project based on review of recent estimates developed for the Caltrans Active Transportation Benefit-Cost Tool (Fitch et al. 2022)[3] and detailed results from the following research studies: Broach et al. (2012)[4], Broach and Dill (2015, 2016, 2017)[5], McNeil et al. (2015)[6], and Sevtsuk et al. (2021)[7]. Therefore, we expect 128 new daily users, all pedestrians (984*0.13 = 128 pedestrians) along South Main Street / Festival Street after implementation of the proposed improvements as shown in Table 6.

Table 6. Demand Estimate

Project Name	Length (Mi)	Estimated Daily Average of Bike Trips	Estimated Daily Average of Pedestrian Trips	Average Daily Users
Festival Street	0.3	0	128	128

[3] Fitch, D.T., S. Kamalapuram, M. Favetti, and S.L. Handy. 2022. Caltrans Active Transportation Benefit-Cost Tool. Technical Documentation, Institute for Transportation Studies, University of California, Davis, Version 0.1.0. Last updated July 31, 2022.
<https://activetravelbenefits.ucdavis.edu/Caltrans%20ATP%20BC%20Tool%20Technical%20Documentation%20Final%20Draft.pdf>.
[4] Broach, J., J. Dill, and J. Gliebe. 2012. "Where Do Cyclists Ride? A Route Choice Model Developed with Revealed Preference GPS Data." Transportation Research Part A: Policy and Practice 46(10), 1730–1740.
[5] Broach, J., and J. Dill. 2015. Pedestrian Route Choice Model Estimated from Revealed Preference GPS Data. In Transportation Research Board 94th Annual Meeting. Washington, DC.; Broach, J., and J. Dill. 2016. "Using Predicted Bicyclist and Pedestrian Route Choice to Enhance Mode Choice Models." Transportation Research Record 2564(1), 52–59. Broach, J., and J. Dill. 2017. Bridging the Gap: Using Network Connectivity and Quality Measures to Predict Bicycle Commuting. Paper presented at the 96th Annual Meeting of the Transportation Research Board.
[6] McNeil, N., C.M. Monsere, and J. Dill. 2015. "Influence of Bike Lane Buffer Types on Perceived Comfort and Safety of Bicyclists and Potential Bicyclists." Transportation Research Record 2520(1), 132–142.
[7] Sevtsuk, A., R. Basu, X. Li, and R. Kalvo. 2021. "A Big Data Approach to Understanding Pedestrian Route Choice Preferences: Evidence from San Francisco." Travel Behaviour and Society 25, 41–51. https://doi.org/10.1016/j.tbs.2021.05.010.

Benefits

The various benefits expected to result from implementation of the project are described in this section.

Walking and Biking Activity

The BCA estimated current levels of walking and biking within the project area using American Community Survey (ACS) 2021 5-year data. Table 7 displays the existing commute to work mode share for people within walking and biking distance of the proposed project. Population and demographic forecasts from Land of Sky Regional Council at the Transportation Analysis Zone (TAZ) level were used to estimate population growth in the study area over the analysis period. Actual population data from 2015 and forecasts for 2045 were collected and were interpolated for each intermediate year in the analysis.

Table 7: Means of Transportation to Work of People Living in the Study Area (2021 American Community Survey)

Corridor	Employed Population	Drove Alone	Carpool	Public Transit	Bicycled	Walked	Worked from Home	Other
Walkshed (within one-half-mile)	5,579	4,027	932	53	0	166	383	18
Bikeshed (within 3 miles)	27,761	21,827	2,837	54	16	363	2,188	462

The means of transportation to work data was converted to daily estimates and extrapolated to annual trip volumes and broken into different trip types (i.e. commute, school, college, and utilitarian) using the existing travel patterns (Table 8) and data from the National Household Transportation Survey. The annual extrapolations account for the expected number of trips per week by trip type (i.e., commute, school, and college trips are expected five out of seven days a week, and other trip types are expected to occur seven days a week).

Table 8: Trip Purpose Multiplier[8]

	Bike	Walk
Utilitarian Trip Multiplier	5.33	8.77

[8] Travel Day Person Trips (in millions), NHTSA 2017 https://nhts.ornl.gov/

Increase in Walking and Biking Activity

The Baseline scenario assumes that the walking and biking mode share will remain constant and that trips will increase annually with expected population growth. In the Build scenario, the demand estimates for the proposed project were added to the existing walking and biking activity starting in 2029 (the expected opening year). The demand estimates were escalated by the expected population growth factor each year.

Decrease in Motor Vehicle Trips

Some of the estimated annual bicycle and pedestrian trips within the proposed project area are expected to replace motor vehicle trips. Calibrated to modal shift factors reported in literature[9], a univariate regression model estimates the motor vehicle trip replacement factor based on the percentage of trips less than four miles that terminate in census block groups within three miles (approximate bicycling distance) of the proposed facility. Trip distance data is provided by Replica for a typical travel in the Hendersonville region on a Thursday in Spring 2024[10]. More details on Replica are included in Appendix A. The motor vehicle trip replacement factor for the proposed project is 0.0876. Additional details on the methodology are included in Appendix B.

To estimate the number of vehicle-miles that might be replaced by bicycling and walking trips, Table 9 shows the average trip distance of bicycling and walking trips by trip purpose. The number of vehicle miles reduced due to bicycle and pedestrian trips was calculated by multiplying the number of biking or walking trips by the trip replacement and trip distance factors. The estimated reduction in vehicle miles traveled is shown in Table 16.

Table 9: Average Trip Distance (miles)

	Bike	Walk
Commute Trips[11]	2.47	0.72
College Trips[12]	1.31	0.43
K-12 School Trips[13]	1.36	0.69
Utilitarian Trips[14]	2.28	0.83

[9] Volker et al (2019). Quantifying Reductions in Vehicle Miles Traveled from New Bike Paths, Lanes, and Cycle Tracks
[10] Replica Places (2019). https://replicahq.com/
[11] NHTS (2017). http://nhts.ornl.gov/tables09/fatcat/2009/aptl_TRPTRANS_WHYTRP1S.html
[12] Ibid.
[13] Safe Routes National Center for Safe Routes to School, Trends in Walking and Bicycling to School from 2007 to 2013 (2015).
[14] NHTS (2017). http://nhts.ornl.gov/tables09/fatcat/2009/aptl_TRPTRANS_WHYTRP1S.html

Environmental Sustainability Benefits

For every vehicle-mile reduced, there is an assumed decrease in greenhouse gases and criteria pollutants. Table 10 lists the reduction in greenhouse gases and criteria pollutants by vehicle-mile traveled. The cost to mitigate or clean-up those pollutants was calculated using the monetary values provided by the USDOT BCA Guidance Table A-6. Emission types not listed in that table were not included in the analysis. The estimated annual emission reduction benefits are shown in Table 17.

Table 10: Environmental Sustainability Multipliers

Pollutant	Value (metric tons/VMT)
Particulate Matter 2.5 ($PM_{2.5}$) [15]	0.000000008
Nitrous Oxides (NOx) [16]	0.0000008
Sulfur Oxides (SO_2) [17]	0.000000008
Carbon Dioxide[18]	0.00044

Quality of Life Benefits

More people bicycling and walking can help encourage an increase in physical activity levels, increased cardiovascular health, and other positive outcomes for users. The benefits from reduced mortality were calculated using the recommended values provided in the USDOT BCA Guidance (Table A-13) and the national distribution of age ranges and travel patterns. These benefits were only applied to the estimated number of walking and biking trips induced by the project (see Demand section). Table 11 displays the multipliers that were used. The estimated annual mortality benefits are shown in Table 18.

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[15] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf
[16] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf
[17] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018) https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf
[18] Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

Table 11: Mortality Reduction Multipliers

Mortality Reduction Benefits of Induced Active Transportation	Value
Walking Value per Induced Trip	$8.06
Cycling Value per Induced Trips	$7.18
Walking Age Proportion (20-74 years old)	68%
Cycling Age Proportion (20-64 years old)	59%
Trips induced from non-active modes	89%

Economic Competitiveness Benefits

For every vehicle-mile reduced, there is a reduction in household transportation costs and congestion costs. Table 12 displays the multipliers use to calculate economic competitiveness benefit. The estimated annual economic competitiveness benefits are shown in Table 19.

Table 12: Economic Competitiveness Multipliers

Type of Savings	Value
Household Transportation Cost Savings	$0.43 per VMT[19]
Congestion Cost Savings	$0.06 per VMT[20,21]

[19] Our Driving Costs, AAA (2016).
[20] Crashes vs. Congestion: What's the Cost to Society? AAA (2011). https://exchange.aaa.com/wp-content/uploads/2012/07/AAA-Crashes-vs-Congestion-2011.pdf
[21] Crashes vs. Congestion: What's the Cost to Society? AAA (2011). https://exchange.aaa.com/wp-content/uploads/2012/07/AAA-Crashes-vs-Congestion-2011.pdf

Safety Benefits

The proposed project would decrease conflicts between people walking and biking with motor vehicles. Collision data covering a five-year period (January 1, 2019- September 1, 2024) was provided by the North Carolina Department of Transportation. Collisions under consideration were located along the project corridor and included all types of collisions due to the various benefits of the proposed improvements (Table 13).

A total of 29 crashes were included in the analysis, including one fatality, a pedestrian who was struck while crossing at an intersection. Different Crash Reduction Factors were applied to the selected crashes for each segment of the project and the benefits were monetized using the values provided in the USDOT BCA Guidance Appendix A, Table A-1 for KABCO Level data.

Each crash was assigned to a single countermeasure. The countermeasures selected were:

- Corridor-specific traffic calming (Caswell St to Allen St) for injury crashes (CM ID 587, CRF 0.18); non-injury crashes (CM ID 590, CRF 0.06)
- Leading pedestrian interval (intersections with Caswell St and Barnwell St) for one pedestrian crash (CM ID 8893, CRF 0.13); injury crashes (CM ID 8892, CRF 0.14)
- Upgrading signal heads from 8-inch to 12-inch signal heads (intersections with Caswell St and Barnwell St) for angle crashes (CM ID 10117, CRF 0.42); non-angle crashes (CM ID 4776, CRF 0.03)
- Pedestrian countdown signals (intersections with Caswell St and Barnwell St) for rear-end crashes (CM ID 10117, CRF 0.13)

The estimated annual safety benefits are shown in Table 20.

Table 13: Summary of Collisions in project corridor, January 1, 2019- September 1, 2024, NCDOT

CMF	Total Collisions	Fatal (K)	Incapacit-ating (A)	Serious (B)	Possible (C)	PDO (O)	Injured – Unknown Severity (U)
Corridor-specific traffic calming – Injury	1	0	0	0	1	0	0
Corridor-specific traffic calming – No Injury	2	0	0	0	0	2	0
Leading pedestrian interval – pedestrian	1	1	0	0	0	0	0
Leading pedestrian interval - injury	1	0	0	0	0	0	1
Upgrading signal heads - angle	14	0	0	0	3	11	0
Upgrading signal heads – non-angle	4	0	0	0	0	4	0
Pedestrian Countdown Signals	6	0	0	0	0	6	0
Total	29	1	0	0	4	23	1

State-of-good Repair Benefits

Table 14 shows the estimated roadway maintenance cost savings associated with a reduction in vehicle-miles traveled.

Table 14: State of Good Repair Multiplier

	Value (metric tons/VMT)
Roadway Maintenance Cost Savings	$0.05 per VMT[22]

[22] Kitamura, R., Zhao, H., and Gubby, A. R. Development of a Pavement Maintenance Cost Allocation Model. Institute of Transportation Studies, University of California, Davis. https://trid.trb.org/view.aspx?id=261768

Results

Table 15 through Table 24 display the results of the benefit-cost analysis for each year of the analysis period. This BCA estimates the project compared to the no-build scenario over a 23-year evaluation (2026-2048) and at a 3.1 percent real discount rate (2.0 percent for carbon) will have a net present value of **$927,000** and a benefit-cost ratio of **1.13 : 1.0.**

Table 15: Estimated Annual Bicycle and Walk Trips

Year	Baseline	Build Scenario	Additional Trips
2026	1,265,800	1,265,800	-
2027	1,266,400	1,266,400	-
2028	1,267,100	1,267,100	-
2029	1,267,700	1,311,700	44,000
2030	1,268,300	1,312,900	44,600
2031	1,268,900	1,314,200	45,300
2032	1,269,600	1,315,500	45,900
2033	1,270,200	1,316,700	46,500
2034	1,270,800	1,318,000	47,200
2035	1,271,400	1,319,300	47,900
2036	1,272,100	1,320,600	48,500
2037	1,272,700	1,322,000	49,300
2038	1,273,300	1,323,300	50,000
2039	1,273,900	1,324,600	50,700
2040	1,274,600	1,326,000	51,400
2041	1,275,200	1,327,300	52,100
2042	1,275,800	1,328,700	52,900
2043	1,276,400	1,330,100	53,700
2044	1,277,100	1,331,500	54,400
2045	1,277,700	1,332,900	55,200
2046	1,278,300	1,334,300	56,000
2047	1,278,900	1,335,700	56,800
2048	1,279,600	1,337,200	57,600
Total Additional Trips:		1,010,000	

Table 16: Estimated Annual Vehicle Miles Reduced

Year	Baseline	Build Scenario	Additional Vehicle Miles Reduced
2026	99,800	99,800	-
2027	99,900	99,900	-
2028	99,900	99,900	-
2029	100,000	103,100	3,100
2030	100,000	103,200	3,200
2031	100,100	103,300	3,200
2032	100,100	103,400	3,300
2033	100,200	103,500	3,300
2034	100,200	103,600	3,400
2035	100,300	103,700	3,400
2036	100,300	103,800	3,500
2037	100,400	103,900	3,500
2038	100,400	104,000	3,600
2039	100,500	104,100	3,600
2040	100,500	104,200	3,700
2041	100,600	104,300	3,700
2042	100,600	104,400	3,800
2043	100,700	104,500	3,800
2044	100,700	104,600	3,900
2045	100,800	104,700	3,900
2046	100,800	104,800	4,000
2047	100,900	104,900	4,000
2048	100,900	105,000	4,100
Total Additional Vehicle Miles Reduced:		72,000	

Table 17: Estimated Annual Environmental Sustainability Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$14,400	$14,900	$500
2030	$14,700	$15,200	$500
2031	$14,900	$15,400	$500
2032	$15,100	$15,600	$500
2033	$15,300	$15,800	$500
2034	$15,500	$16,000	$500
2035	$15,700	$16,200	$500
2036	$15,900	$16,400	$500
2037	$16,100	$16,700	$600
2038	$16,300	$16,900	$600
2039	$16,500	$17,100	$600
2040	$16,700	$17,300	$600
2041	$16,900	$17,500	$600
2042	$17,100	$17,800	$700
2043	$17,400	$18,000	$600
2044	$17,600	$18,200	$600
2045	$17,800	$18,500	$700
2046	$18,000	$18,700	$700
2047	$18,300	$19,000	$700
2048	18,500	19,200	$700
Total Benefits:			$11,700

Table 18: Estimated Annual Quality of Life Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$6,102,000	$6,317,000	$215,000
2030	$6,105,000	$6,323,000	$218,000
2031	$6,108,000	$6,329,000	$221,000
2032	$6,111,000	$6,335,000	$224,000
2033	$6,114,000	$6,341,000	$227,000
2034	$6,117,000	$6,347,000	$230,000
2035	$6,120,000	$6,354,000	$234,000
2036	$6,123,000	$6,360,000	$237,000
2037	$6,126,000	$6,367,000	$241,000
2038	$6,129,000	$6,373,000	$244,000
2039	$6,132,000	$6,379,000	$247,000
2040	$6,135,000	$6,386,000	$251,000
2041	$6,138,000	$6,393,000	$255,000
2042	$6,141,000	$6,399,000	$258,000
2043	$6,144,000	$6,406,000	$262,000
2044	$6,147,000	$6,413,000	$266,000
2045	$6,150,000	$6,420,000	$270,000
2046	$6,153,000	$6,426,000	$273,000
2047	$6,156,000	$6,433,000	$277,000
2048	6,159,000	6,440,000	$281,000
Total Benefits:			$4,931,000

Table 19: Estimated Annual Economic Competitiveness Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$60,400	$62,300	$1,900
2030	$60,400	$62,400	$2,000
2031	$60,500	$62,400	$1,900
2032	$60,500	$62,500	$2,000
2033	$60,500	$62,500	$2,000
2034	$60,500	$62,600	$2,100
2035	$60,600	$62,600	$2,000
2036	$60,600	$62,700	$2,100
2037	$60,600	$62,800	$2,200
2038	$60,700	$62,800	$2,100
2039	$60,700	$62,900	$2,200
2040	$60,700	$62,900	$2,200
2041	$60,800	$63,000	$2,200
2042	$60,800	$63,100	$2,300
2043	$60,800	$63,100	$2,300
2044	$60,800	$63,200	$2,400
2045	$60,900	$63,300	$2,400
2046	$60,900	$63,300	$2,400
2047	$60,900	$63,400	$2,500
2048	$61,000	$63,500	$2,500
Total Benefits:			$43,700

Table 20: Estimated Annual Safety Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$-	$339,000	$339,000
2030	$-	$339,000	$339,000
2031	$-	$339,000	$339,000
2032	$-	$339,000	$339,000
2033	$-	$339,000	$339,000
2034	$-	$339,000	$339,000
2035	$-	$339,000	$339,000
2036	$-	$339,000	$339,000
2037	$-	$339,000	$339,000
2038	$-	$339,000	$339,000
2039	$-	$339,000	$339,000
2040	$-	$339,000	$339,000
2041	$-	$339,000	$339,000
2042	$-	$339,000	$339,000
2043	$-	$339,000	$339,000
2044	$-	$339,000	$339,000
2045	$-	$339,000	$339,000
2046	$-	$339,000	$339,000
2047	$-	$339,000	$339,000
2048	$-	$339,000	$339,000
Total Benefits:			$ 6,780,000

Table 21: Estimated Annual State of Good Repair Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$9,000	$9,300	$300
2030	$9,000	$9,300	$300
2031	$9,000	$9,300	$300
2032	$9,000	$9,300	$300
2033	$9,000	$9,300	$300
2034	$9,000	$9,300	$300
2035	$9,000	$9,300	$300
2036	$9,000	$9,300	$300
2037	$9,000	$9,300	$300
2038	$9,000	$9,400	$400
2039	$9,000	$9,400	$400
2040	$9,000	$9,400	$400
2041	$9,100	$9,400	$300
2042	$9,100	$9,400	$300
2043	$9,100	$9,400	$300
2044	$9,100	$9,400	$300
2045	$9,100	$9,400	$300
2046	$9,100	$9,400	$300
2047	$9,100	$9,400	$300
2048	$9,100	$9,500	$400
Total Benefits:			$6,400

Table 22: Estimated Annual Maintenance Disbenefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026			
2027			
2028			
2029	$-	$(50,000)	$(50,000)
2030	$-	$(50,000)	$(50,000)
2031	$-	$(50,000)	$(50,000)
2032	$-	$(50,000)	$(50,000)
2033	$-	$(50,000)	$(50,000)
2034	$-	$(50,000)	$(50,000)
2035	$-	$(50,000)	$(50,000)
2036	$-	$(50,000)	$(50,000)
2037	$-	$(50,000)	$(50,000)
2038	$-	$(50,000)	$(50,000)
2039	$-	$(50,000)	$(50,000)
2040	$-	$(50,000)	$(50,000)
2041	$-	$(50,000)	$(50,000)
2042	$-	$(50,000)	$(50,000)
2043	$-	$(50,000)	$(50,000)
2044	$-	$(50,000)	$(50,000)
2045	$-	$(50,000)	$(50,000)
2046	$-	$(50,000)	$(50,000)
2047	$-	$(50,000)	$(50,000)
2048	$-	$(50,000)	$(50,000)
Total Benefits:			$(1,000,000)

Table 23: Estimated Annual Benefits (Undiscounted)

Year	Baseline	Build Scenario	Benefits
2026	$-	$-	$-
2027	$-	$-	$-
2028	$-	$-	$-
2029	$6,186,000	$6,692,000	$506,000
2030	$6,189,000	$6,698,000	$509,000
2031	$6,193,000	$6,705,000	$512,000
2032	$6,196,000	$6,711,000	$515,000
2033	$6,199,000	$6,718,000	$519,000
2034	$6,202,000	$6,724,000	$522,000
2035	$6,205,000	$6,730,000	$525,000
2036	$6,209,000	$6,738,000	$529,000
2037	$6,212,000	$6,744,000	$532,000
2038	$6,215,000	$6,751,000	$536,000
2039	$6,218,000	$6,757,000	$539,000
2040	$6,222,000	$6,765,000	$543,000
2041	$6,225,000	$6,771,000	$546,000
2042	$6,228,000	$6,778,000	$550,000
2043	$6,232,000	$6,786,000	$554,000
2044	$6,235,000	$6,793,000	$558,000
2045	$6,238,000	$6,799,000	$561,000
2046	$6,241,000	$6,806,000	$565,000
2047	$6,245,000	$6,814,000	$569,000
2048	$6,248,000	$9,488,000	$3,240,000
Total Benefits:			$13,430,000

Table 24: Estimated Discounted Net Costs and Benefits (carbon discounted at 2.0%, all others Discounted at 3.1%)[23]

Year	Discounted Costs	Discounted Benefits	Net Cumulative Discounted Costs and Benefits
2026	$(1,825,000)	$-	$(1,825,000)
2027	$(3,540,000)	$-	$(5,365,000)
2028	$(1,717,000)	$-	$(7,082,000)
2029	$-	$421,000	$(6,661,000)
2030	$-	$411,000	$(6,250,000)
2031	$-	$401,000	$(5,848,000)
2032	$-	$392,000	$(5,457,000)
2033	$-	$382,000	$(5,075,000)
2034	$-	$373,000	$(4,702,000)
2035	$-	$364,000	$(4,337,000)
2036	$-	$356,000	$(3,982,000)
2037	$-	$347,000	$(3,635,000)
2038	$-	$339,000	$(3,296,000)
2039	$-	$331,000	$(2,965,000)
2040	$-	$323,000	$(2,642,000)
2041	$-	$315,000	$(2,327,000)
2042	$-	$308,000	$(2,019,000)
2043	$-	$301,000	$(1,718,000)
2044	$-	$294,000	$(1,424,000)
2045	$-	$287,000	$(1,137,000)
2046	$-	$280,000	$(857,000)
2047	$-	$274,000	$(583,000)
2048	$-	$1,510,000	$927,000
Total Net Discounted Costs: $ 7,082,000		Total Discounted Net Benefits: $8,009,000	Net Present Value: $927,000
Benefit-Cost Ratio: 1.13:1			

[23] Carbon reduction benefits were discounted at 2%.

Appendix A: Technical Documentation.
Replica Methodology

replica methodology

0. About Replica

Replica is a data platform for the built environment. By combining powerful data insights with an uncompromising approach to privacy, Replica provides a holistic view into the ways mobility, land use, and economic activity intersect. Our approach to delivering insights to our customers is rooted in using a composite of data sources to do advanced modeling and simulation of activity across time and space.

I. Executive Summary

At Replica, we understand that data is only valuable when you can trust it to inform analysis and decision-making. To that end, this document outlines data sources, data processing methods, and data outputs for Replica Places, Trends, and Scenario, to help our customers[1] evaluate the quality and accuracy of our models, and assess data privacy implications.

Replica Places are high-fidelity activity-based travel models[2] that simulate the movements of residents, visitors, and commercial vehicles in a given area. Replica produces Places models as “megaregions,” most of which cover between 10 and 50 million people and multiple states, for a typical weekday and typical weekend day in a given season. Data outputs can be queried down to the network link level.

Replica Trends is a nationwide activity-based model updated each week with near-real-time data on mobility, consumer spending, and land use. Trends has census-tract-level fidelity with mobility data including origins and destinations, trip mode, and residential vehicle miles traveled (VMT), and total consumer spending data across a number of sub-categories, including retail, grocery stores, restaurants, and travel.

Replica Scenario is the first tool that allows anyone working with the built environment to easily forecast travel activities anywhere in the country. With Scenario, public agencies and their consultants can obtain high-quality, detailed data projections of future conditions based on expected changes to the population, land use, and transportation infrastructure.

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[1] Replica has served over 100 clients throughout the U.S., including Caltrans (the California Department of Transportation [DOT]), the Metropolitan Transportation Authority in New York, the NY State Division of the Budget, the Illinois DOT, NJ TRANSIT, and the Office of the Chief Technology Officer (OCTO) in Washington, D.C.

[2] Activity-based models are transportation models in which travel demand is derived from people's daily activity patterns. Activity-based models represent which activities are conducted when, where, for how long, for and with whom, and the travel choices they will make to complete them.

Replica generates its data by running large-scale, computationally intensive simulations. These simulations allow us to deliver granular data outputs that match behavior in aggregate, but don't surface the actual movements (or compromise the privacy) of any one individual.

Rather than simply cleansing, normalizing, and scaling individual data sources, Replica uses a composite of data sources to:

(1) Create a synthetic population that matches the characteristics of a given region

(2) Train a number of behavior models specific to that region

(3) Run simulations of those behavior models applied to the synthetic population in order to create a "replica" of transportation and economic patterns

(4) Calibrate the outputs of the model against observed "ground-truth" to improve quality

In our data outputs, origin-destination pairs are consistent with human activities. Population demographics are accurate and correlate with appropriate movement. Recurring activities are coherent over time and capture a pattern of life. Routing between locations is consistent with local road networks and transportation options, and the scale of population and number of trips is appropriate for a given geographic extent.

In the following document, we outline our sources, methodology, and outputs, as well as detail regarding our uncompromising approach to protecting individual privacy.

II. Source Data

Replica builds its simulations using a diverse set of third-party data from public and private-sector sources. These sources include five categories of data:

Mobile location data: To create a representative sample of daily movement patterns within a place, Replica uses multiple types of mobile location data as inputs to our model – location-based services (LBS) data collected from personal mobile devices; vehicle in-dash GPS data; and point-of-interest aggregates. Previous versions of Replica's model also included cellular networks data as another source of mobile location data. Replica only acquires de-identified mobile location data.

Consumer / resident data: Demographic data from public and private sources provides the basis for determining where people live and work, and the characteristics of the population, such as age, race, income, and employment status.

Built environment data: Land use data (such as zoning regulations), building data (such as total square footage and use types), and transportation network data (such as road and transit networks) are used to determine where people live, work, and shop, and by what means it is possible to travel to each activity.

Economic activity data: Includes all transactions, including credit card, debit card, and cash transactions, that take place at a point of sale. With this input, Replica depicts the level and types of spending that occurred at a particular time and place.

Ground truth data: Ground truth data is used to calibrate and improve the overall accuracy of Replica outputs. The types of ground truth collected by Replica include auto and freight volumes, transit ridership, and bike and pedestrian counts. Ground truth is both acquired directly by Replica and provided by customers.

Each of Replica's data processing pipelines leverages a composite of these diverse data sets. This process minimizes the risk of sampling bias that exists in any single source on its own. For example, a product that relies more heavily on data from personal mobile devices risks failing to adequately simulate the portions of the population that do not have mobile devices or those who opt out of device tracking technologies. Our composite approach also creates resiliency against data quality issues and protects against disruptions of individual data sources.

III. Replica Places Overview

Replica Places simulations reflect the complete activities and movements of residents, visitors, and commercial vehicle fleets in a region and season on a typical day. Places are delivered as megaregions, most of which cover between 10 and 50 million residents and multiple states, enabling the entire contiguous United States and Hawaii to be produced in a small number of megaregions.

The output of each simulation is a complete, disaggregate trip and population table for an average weekday and average weekend day in the subject season (e.g., Fall 2021). The model represents a 24-hour period with second-by-second temporal resolution, and point-of-interest-level spatial resolution. Each row of data in the simulation output reflects a single trip, with characteristics about both the trip (e.g, origin, destination, mode, purpose, routing, duration) and trip taker (e.g., age, race/ethnicity, income, home location, work location).

Each completed model also includes an associated quality report, which compares the outputs of the simulation to ground truth data, enabling customers to compare Replica's modeled outputs with observed counts.

Replica updates Places models annually.

IV. Replica Places Methodology

Replica's process to generate its Places simulations is best described in four steps:

Step 1: Create Synthetic Population. Each year, Replica generates a nationwide synthetic population, statistically equivalent to the actual population, for the entirety of the United States. Replica creates a synthetic population in order to overcome the limitations of census data, which is only provided at the aggregate level. Synthetic populations allow Replica to assign attributes to individuals and households while protecting privacy and preserving spatial fidelity.

The synthetic population is generated using census and consumer marketing data. Replica applies data science techniques to this data that allow for: (1) modeling the dependencies in socio-demographic parameters and structure of the households, and (2) generating individual households that match census information at the required level of aggregation, such as block groups or tracts.

Each synthetic household consists of people with an assigned set of attributes: age, sex, race, ethnicity, employment status, household income, vehicle ownership status, and resident or visitor status. Workplace locations for all employed individuals are assigned based on the combination of mobile location data aggregates and census information. These assignments are static in each seasonal model, but can and do change across seasons.

To begin each specific Places deployment, the population relevant for the specific megaregion and season is extracted from the nationwide population.

Step 2: Create Mobility Model. Modern machine learning techniques are then used to develop travel personas. Personas are based on the composite of mobile location data for the megaregion and specific season. Personas are an extraction of behavioral patterns from individual devices that live in, work in, travel to, travel from, or pass through a specific region during the modeled season. Each persona is composed of three underlying behavioral-choice models: activity planning and sequencing (e.g., at home -> drive to work -> at work -> drive to shop -> at shop -> drive to home), destination location choice (i.e., the exact location people are traveling to and from), and travel mode (i.e., the chosen mode).

Replica's mobile-location data represents anywhere from 5% to 20% of a local population. Replica intentionally only acquires what data is necessary to build statistically representative models, another tenet of balancing model fidelity with user privacy.

Step 3: Generate Activity. To simulate activity, the outputs from Step 1 and Step 2 are joined. Each synthetic household is assigned one or more personas using home and work locations as a primary input, enhanced with matching by available socio-demographic attributes and by the role of the person in a household. In effect, with travel behavior models assigned, each synthetic person can now make choices about when, where, and how to travel.

Replica uses three models to assign movements to the individuals in the synthetic population. The **activity sequence model** determines the activities of a person's day, including recurring activities (e.g., travel to work, school drop off), and one-time activities (e.g., shopping, visiting a restaurant, social visit to a friend's residence). The **location choice model** determines the specific location of each discretionary activity (e.g., what restaurant is chosen for lunch, where grocery shopping gets done), assigning a location at the point-of-interest level. The **mode choice model** determines how the trip will be made based on the state of the transportation network, accounting for available transit options and multiple driving routes.

Movement is then simulated with an agent-based approach that accounts for congestion and other interactions between individual travel itineraries.

Step 4: Calibrate. After each individual simulation is run, the modeled outputs are compared to aggregate control group data (i.e., observed counts, or "ground truth") for quality and reporting purposes. This calibration process involves solving a set of large-scale optimization problems with an objective function defined as "fit to observed ground truth." We strike a careful balance to ensure that the calibration algorithms do not overfit the modeled outputs to the calibration data, as both outliers and a certain level of noise are often present in every dataset.

To complete this iterative calibration process, Replica always holds out some of its own ground truth data from the initial mobility simulation. Replica can also incorporate additional ground truth provided by its customers for additional quality enhancement.

As noted earlier, when a completed model is published, customers also have access to an associated quality report.

V. Replica Places Data Outputs

Each simulation results in a complete trip, population, and routing table.

Population Attributes: Each trip is associated with a specific person in the simulation, for whom the following characteristics are available:

- Age
- Sex
- Race and ethnicity
- Primary language
- Employment status
- Industry of employment
- Home location
- Work location
- Individual and household income
- Work-from-home status
- Vehicle ownership status
- Resident or visitor status

See full list of attributes available here.

Trip Attributes: Each trip is assigned the following attributes:

- Origin and destination points
- Origin and destination points by land use category
- Trip distance
- Trip duration
- Start and end time
- Complete routing information for each trip (network links and transit routes)
- Trip mode, including private auto driver, private auto passenger, public transit, walking, biking, freight, and transportation network companies (TNCs)
- Trip purpose, including home, work, errands, eat, social, shop, recreation, commercial, and school

See full list of attributes available here.

Location Detail: Replica models to specific real-world locations and points of interest (e.g., a specific office building, the Starbucks at a certain address) — trips are modeled from individual building footprint to individual building footprint, rather than zone to zone. We update our nationwide catalog of points of interest monthly, and we use the applicable set of locations for each simulation.

VI. Replica Trends Overview, Methodology, and Outputs

Replica produces its Trends dataset on a weekly basis, providing near-real-time insight into mobility and spending patterns.

The output of Trends is a series of data points for each census tract in the country, delivered weekly. Trends includes data from the start of 2019 and onwards, enabling year-over-year comparisons.

Mobility Data

- Complete hourly nationwide OD table, representing an average day in the prior week (link)
- Mode Split (including auto, transit, walking, and biking) (link)
- Residential Vehicle Miles Traveled (link)

Economic Data

- Total dollars of Consumer Spend by all residents of each census tract, and at all merchants in each census tract, across the below categories. Learn more about weekly spend by home location and weekly spend by merchant location.
  - Retail
  - Grocery Stores
  - Gas Stations, Parking, Taxis, Tolls
  - Restaurants & Bars
  - Airline, Hospitality, & Car Rental
  - Entertainment & Recreation

- Breakdown of on- and off-line spend for certain categories
- Spend county-to-county flows by merchant location and resident location, broken down by sector (link)

Additional Data

- Summary Demographic and Household Data
- Land Use Data

In order to produce these outputs, Replica runs a modified version of its Places pipeline on a daily basis. The Trends pipeline leverages the same synthetic population and travel personas as described in the Places methodology above. However, there are three primary differences in the data processing pipeline:

- First, because the pipeline is run for the entire country on a daily basis, limitations in computing power mean that trip mode is modeled with a modified router that does not provide network link or transit line-level detail.
- Second, because weekly deliveries make it impossible to receive ground-truth data from customers for calibration, Trends outputs are calibrated internally from different sources (e.g., comparing mobile location data to in-vehicle GPS data). We also compare our Trends data to previously released, calibrated Places models.
- Third, Trends does not currently model visitor or freight trips. We plan to add these trip estimates in a future update.

In effect, these differences in the pipeline reflect a trade-off of granularity and detail for speed of delivery, in order to maintain consistent quality. To that end, Trends data is best used for monitoring changes over time, and Places data is best used for in-depth point-in-time analysis that may benefit from the ability to do cross-tabular filtering and individual trip analysis.

VII. Replica Scenario Overview, Methodology, and Outputs

Scenario is an extension of our core Places modeling pipeline, updated to be able to accept new input data representing growth and/or investment scenarios. We currently accept changes to population, employment, work from home rates, and roadway networks to model associated impacts on travel behavior and the broader transportation network.

Our travel synthesis pipeline in Scenario leverages the activity sequence model, location choice model, and mode choice model from our Places modeling pipeline, with certain changes, including to traffic and transit assignment. For traffic assignment, we adopt an approach where we estimate the true physical capacity of road segments, replicating the traditional speed/flow approach (based on the Highway Capacity Manual) for every major road in the country that reaches capacity in the data that we have. We then use these physical capacities to constrain the number of trips that can be routed along each road option. When a road is at capacity, subsequent travelers will take an alternate route or adjust their departure time to accommodate.

For transit assignment in Scenario, we model forecasted line-level totals based off of a Base Year run, which has detailed trip information associating origin and destination geographies with specific transit services. We start with each tract-level origin/destination pair, and scale the number of Base Year trips that traveled on each transit line, using a weighted average of population and employment changes in the origin and destination tract. Then, we sum the totals across all origin/destination pairs to get updated line-level ridership estimates. This allows our model to be responsive to local changes in population and employment forecasts with high granularity.

The outputs of Scenario include the following data:

- New population, employment, and home-work distribution
- Travel behaviors (origins, destinations, mode choice, trip distances, etc.)
- Road volumes and transit line ridership
- Locations where travel demand exceeds road capacity

VIII. Complementary Datasets

In addition to the core Places, Trends, and Scenario datasets, Replica makes additional, complementary datasets available to its customers. These include:

- Nationwide synthetic population (link)
- Nationwide parcel-level land use data, including both parcel area and building area data (link)
- Nationwide Annual Average Daily Traffic (AADT) data (link)
- Nationwide Annual Free-Flow Speeds data (link)
- Nationwide Quarter-Hourly Speed Profiles (link)
- Nationwide Turning Movement Count (TMC) data (link)

IX. Applications

Our applications provide end-to-end solutions for extracting insights from Replica data, accelerating analyses and facilitating quick access to answers. Complementing our core datasets, including Places, Trends, and Scenarios, these applications are tailored to meet the diverse needs of our customers. These include:

- Transit Demand & Equity Application (link)
- TMC Explorer (link)
- Safe Streets Planner (link)
- Network Speeds Viewer (link)
- Network Link Volumes (link)
- AADT Explorer (link)

X. Approach to Privacy

The approach outlined here reflects Replica's uncompromising belief that better insights should not come at the expense of personal privacy. Our methodological approach enables us to provide highly granular output data while remaining faithful to a series of privacy-first technical commitments. At Replica, we:

- Only procure de-identified data from our source vendors. We never receive, use, or output personally identifiable information.
- Never share raw locational data with our customers — or any other third-parties.
- Build models from different data sources independently so that we abstract out potentially identifying details of any individual before combining these models into our aggregate outputs.
- Never join data sources on keys containing sensitive data.
- Incorporate proven techniques, like statistical noise injection, into our algorithms to ensure that (1) it is impossible to ascertain if an individual's information is part of our source data by inspecting our modeled outputs; (2) it is impossible to learn which specific locations were visited by an individual whose information was part of our source data by inspecting our modeled outputs.

Simply put, Replica's methodology results in outputs that make it impossible to track or identify the movements of any individual.

If you have any questions about Replica's products or methodology, please contact support@replicahq.com.

Appendix B: Modal Substitution Rate Methodology

To: BCA Reviewers

From: Grace Young, Rohan Oprisko, Mike Sellinger, and David Wasserman, Alta Planning + Design

Date: April 1, 2022

Re: Modal Shift Model Notes

Modal Substitution Rates: Introduction

Modal substitution rates refer to the percentage of users of a facility who substituted one mode for another (Volker et al. 2019). These rates are often determined from survey instruments asking about alternative modes. When users substitute a carbon-free mode like biking for a carbon-intensive mode like driving, there is an associated emissions savings, proportional to the length of the trip. The following model provides a means for estimating the percentage of future facility users that will substitute a carbon-free mode in place of driving. This serves as a crucial step in identifying reductions in vehicle miles traveled and the emissions-saving benefits of the proposed facility.

Methodology

A series of univariate regression models were tested on peer-reviewed auto-to-bike substitution rates for projects in 10 cities around the United States. Six variables were collected at the city level and tested as inputs in a univariate regression model predicting the modal shift factor using an ordinary least squares regression from the statsmodels Python library. The variables are described in Table 1. The same variables were also tested in predicting the natural log of the modal shift percentage.

Data Review

Table 1. Peer-reviewed auto-to-bike modal shift factor and six demographic variables reported for the respective project cities[1]

City	Modal Shift (ratio)	Population Density (people per sq. mi.)	Median Income ($)	Travel Time to Work (min.)	% of Trips <4 Miles (ratio)	Active Mode Split (ratio)	Bike Mode Split (ratio)	Source
Los Angeles, CA	0.109	8,092	62,142	32	0.471	0.147	0.030	Matute et al. (2016)
Denver, CO	0.237	3,923	68,592	26	0.531	0.251	0.015	Piatkowski et al. (2015)
Boulder, CO	0.571	3,948	69,520	20	0.652	0.283	0.045	Piatkowski et al. (2015)
Littleton, CO[2]	0.724	3,215	76,105	26	0.512	0.254	0.060	Piatkowski et al. (2015)
Sacramento, CA	0.273	4,764	62,335	26	0.437	0.195	0.090	Piatkowski et al. (2015)

City	Modal Shift (ratio)	Population Density (people per sq. mi.)	Median Income ($)	Travel Time to Work (min.)	% of Trips <4 Miles (ratio)	Active Mode Split (ratio)	Bike Mode Split (ratio)	Source
Davis, CA	0.250	6,637	69,3709	23	0.636	0.220	0.095	Piatkowski et al. (2015)
Austin, TX	0.146	2,653	71,576	25	0.502	0.179	0.016	Monsere et al. (2014)
Chicago, IL	0.374	11,841	58,247	35	0.598	0.377	0.070	Monsere et al. (2014)
Portland, OR	0.202	4,375	71,005	27	0.538	0.267	0.027	Monsere et al. (2014)
San Francisco, CA	0.263	17,179	112,449	34	0.547	0.245	0.060	Monsere et al. (2014)
Washington, DC	0.202	9,856	86,420	31	0.564	0.311	0.018	Monsere et al. (2014)

Notes:

min. : minute

sq. mi. : square mile

1. Adapted from Volker et al. 2019.
2. Littleton, CO, was removed as an outlier in this modeling exercise for both final models.
3. All sources can be found in the Volker, J et. al (2019) paper specified in the references section.

Results

We found two acceptable models for contextual estimation of modal substitution rates given the available data: the examination of short trips (under 4 miles) and the active mode split model. Alta's preferred model is the examination of short trips due to its theoretical consistency with the idea that short trips are indicators that a higher proportion of vehicle trips can be converted to active modes given improved infrastructure and support. Alta uses the active mode split model depending on the available data sources on a given project or for sensitivity analysis to generate a conservative estimate.

Correlation and R-Squared

Table 2. Variable performance in correlation test and ordinary least squares univariate regression

Variable	Source	Correlation with Modal Shift	Correlation with ln (Modal Shift)	Adjusted R-Squared Predicting Modal Shift		Adjusted R-Squared Predicting ln (Modal Shift)	
				No Constant	With Constant	No Constant	With Constant
Population Density	Census	-0.21	-0.11	0.411	-0.063	0.663	-0.098

Variable	Source	Correlation with Modal Shift	Correlation with ln (Modal Shift)	Adjusted R-Squared Predicting Modal Shift		Adjusted R-Squared Predicting ln (Modal Shift)	
				No Constant	With Constant	No Constant	With Constant
Median Income	Census	-0.01	0.03	0.689	-0.111	0.813	-0.110
Travel Time to Work	Census	-0.32	-0.30	0.653	0.001	0.864	-0.014
Percent of Trips Under 4 Miles	Replica Places (2022)	0.31	0.41	0.744	-0.005	0.805	0.076
Active Mode Split (all trips)	Replica Places (2022)	0.39	0.53	0.763	0.057	0.709	0.200
Bike Mode Split	Replica Places (2022)	0.32	0.43	0.654	0.003	0.479	0.090

Note:

All values reported in this table are for models without the Littleton, CO outlier removed.

Linear Relationship Plots

Figure 1 and Figure 2 show the linear relationship between the log of modal shift and the percentage of trips less than 4 miles or active mode share, respectively. Littleton, CO, is identified as an outlier in both cases and thus removed for the final model development.

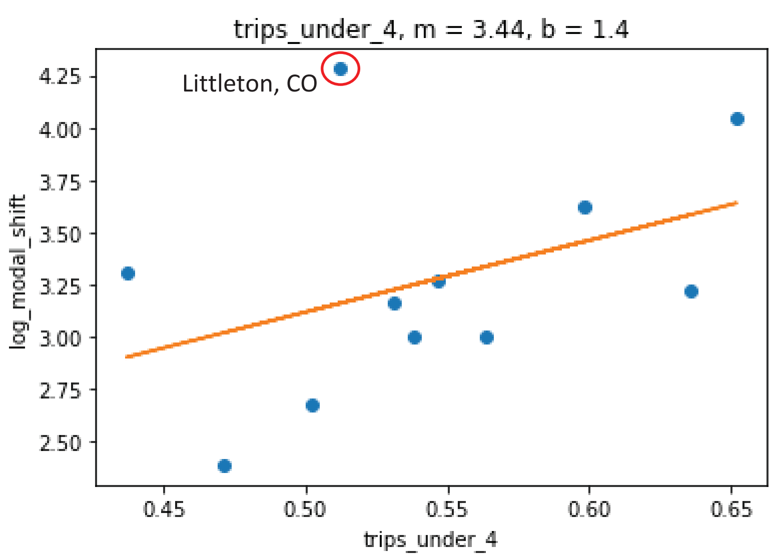

Figure 1. Modeled Relationships Between the Percentage of Short Trips and the Log of Modal Shift

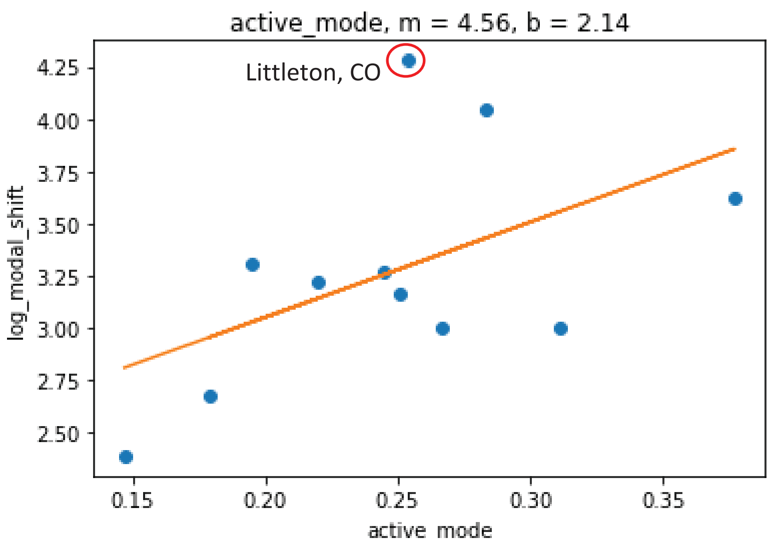

Figure 2. Modeled Relationships Between Active Mode Share and the Log of Modal Shift

Final Model Summaries

The two acceptable models are summarized in Table 3, along with the derived equations for applying each to a project-specific context.

Table 3. Model summaries for acceptable final models

Dependent Variable	*Log modal shift percentage*		Dependent Variable	*Log modal shift percentage*	
R-squared	*0.424*		R-squared	*0.414*	
Independent Variable	Coefficient	P-Value	Independent Variable	Coefficient	P-Value
Percent of trips under 4 miles	4.39	0.041	Active mode share	1.85	0.045
Constant	0.77	0.462	Constant	2.08	0.002
Equation			Equation		
ln(modal shift %) = 0.77 + 4.39*(% trips under 4 miles)			ln(modal shift %) = 2.08 + 1.85*(% active mode share)		

Discussion

These models enable a flexible and actionable approach to provide context-sensitive estimates of potential modal substitution rates given investments in multimodal infrastructure that are suitable for transportation planning practice. This approach aligns well with the understanding that compact, mixed-use locations with small urban footprints and high destination access encourage shorter trips and active travel (NASEM 2014). These models provide a decision-support tool to make informed and context-sensitive assessments of potential modal substitution rates given a project study boundary. Understanding how much reduction in vehicle miles traveled is possible given investments in active transportation is relevant to choosing a quick and responsive model.

However, there are limitations to this approach worth considering:

- While significant relationships were identified between these variables and modal substitution rates from literature, they are based on small sample sizes and depend on the removal of outliers.
- These models are not using any control variables. These univariate linear regression models are intended to enable quick determinations of possible modal substitution given a specific built context. While other variables such as population density or travel time to work were evaluated, they were not used as controls within the same model.
- Many other factors can influence rates of modal substitution beyond those identified here, and they warrant further study. It is highly complex result of localized intercept surveys, but their ranges from literature benefit from a context sensitive approach for analysis.

References

NASEM (National Academies of Sciences, Engineering, and Medicine). (2014). *Estimating Bicycling and Walking for Planning and Project Development: A Guidebook*. Washington, DC: The National Academies Press. https://doi.org/10.17226/22330

Volker, J., S. Handy, A. Kendall, and E. Barbour. (2019). *Quantifying Reductions in Vehicle Miles Traveled from New Bike Paths, Lanes, and Cycle Tracks: Summary Report.* California Air Resources Board (CARB). March 25, 2019.

Replica Places (2022). Replica Platform. Retrieved from https://replicahq.com/

CBI Rationale

These regression equations are the result of internal R&D at Alta and represent a data-driven approach to identifying realistic modal substitution rates given contextual information about a project area. Disclosure of these models before they can be further published in peer review research represents a disincentive for firms to advance research and development to advance context sensitive practice. This research was based on Alta Planning + Designs proprietary know-how and understanding of active transportation research and available data resources to inform them.

Appendix C: Multipliers

This section displays additional multipliers that were used to calculate the benefits throughout this analysis that were not presented in the body of the analysis results.

Safety benefits are a result of the expected reduction in collisions due to the decrease in vehicle miles traveled. **Table C-1** displays the collision cost reduction per vehicle mile traveled.

Table C-1: Collision Costs

Type of Collision	[vi]
Collision Cost Savings	$0.22/VMT

Table C-2 shows the estimated roadway maintenance cost savings associated with a reduction in vehicle-miles traveled.

Table C-2: State of Good Repair Multiplier

Roadway Maintenance Cost Savings	$0.06 per VMT[vii]

Multiplier Notes

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[i] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[ii] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[iii] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[iv] The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars, BUILD Guidance 2020, Table A-7 and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

[v] Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

[vi] Caltrans Highway Safety Improvement Program http://www.dot.ca.gov/hq/LocalPrograms/HSIP/apply_nowHSIP.htm

[vii] Kitamura, R., Zhao, H., and Gubby, A. R. Development of a Pavement Maintenance Cost Allocation Model. Institute of Transportation Studies, University of California, Davis. https://trid.trb.org/view.aspx?id=261768