THE GOODMAN CORPORATION

Telephone Road Reconstruction

Benefit Cost Analysis Narrative

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Executive Summary

The 2023 USDOT Benefit-Cost Analysis (BCA) Guidance for Discretionary Grant Programs provides the foundation for the methodologies used to estimate the quantified and subsequent monetized benefits in this BCA.[1] The evaluation process examines the fundamental question of whether the expected societal benefits of the project justify the cost with the understanding that some benefits and costs are difficult to quantify. This analysis examines how the No-Build and Build Scenarios improve the societal benefits throughout the planning horizon.

The BCA quantifies the net difference between the No-Build and Build Scenarios for the project corridor. The Telephone Road Reconstruction Project ("Project") limits are described in Table 1.

Table 1. Project Limits

Street	Terminus A	Terminus B
Telephone Road	South Loop E (Eastbound Frontage Road)	Reveille Street

The **No-Build Scenario** assumes that the roadway will continue to deteriorate and be minimally maintained throughout the planning horizon. The planning horizon includes 20 years, from 2026 to 2046.

The **Build Scenario** assumes a replacement of infrastructure within public right-of-way (ROW) along the project limits, which will include the following major components:

- Expand existing sidewalks to 6-foot and construct new 6-foot sidewalks to meet the standards of the City of Houston.
- Install pedestrian lighting and high-visibility crosswalks.
- Install a 5-foot dedicated/separated bike lane along the Project corridor.
- Install a figure 8 roundabout at the intersection of Telephone Road and Reveille Street.

Summarized Planning, Design, Environmental, and Capital Costs

The costs (excluding ongoing maintenance) for the Project in the year of expenditure, or nominal dollars, is $54,851,000. The annual inflation factor of 2.44% applied to the projected costs (nominal $), was discounted from the year of expenditure to reflect the real $ in year 2021. The 2.44% inflation factor is derived from the inflation adjustment

1 United States Department of Transportation (2023). Benefit-Cost Analysis Guidance for Discretionary Grant Programs. Retrieved January 2023 from https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance

values found in Table A-7 in the 2023 USDOT BCA Guide.[1] The total project cost in 2021 real dollars is $49,333,000. These costs are discounted 7% from the expenditure year to year 2021. The total year 2021 real discounted costs are $36,699,000. Project costs are described in Table 2.

Table 2. Project Costss

Cost	Nominal $ Year of Expenditure No Discount	Real $ $2021 No Discount	7% Discount $2021
Design/Environmental	$4,047,000	$3,764,000	$3,072,000
Construction	$50,804,000	$45,569,000	$33,627,000
Project Costs	**$54,851,000**	**$49,333,000**	**$36,699,000**

Summarized Benefits

Moving forward with the **Build Scenario** will result in the following monetized societal benefits; however, there are some disbenefits also associated with the Project, as explained below:

Benefits Monetized – Transportation

- **Benefit 1: Remaining Useful Life of Asset**
  - The asset will be built with a useful life of 50 years, therefore there will be 60% remaining useful life at the end of the planning horizon.
- **Benefit 2: State of Good Repair**
  - The Project will replace the pavement, which will significantly reduce vehicle wear and tear and ongoing maintenance costs.
- **Benefit 3: Motorist Safety Improvements**
  - The Project will provide significant safety improvements and as a result, a likely reduction of motor vehicle crashes (separate from pedestrian and bicycle related crashes).
- **Benefit 4: Pedestrian Safety Improvements**
  - The Project will experience significant pedestrian safety improvements and as a result, a likely reduction of pedestrian related injuries.
- **Benefit 5: Bicycle Safety Improvements**
  - The Project will experience significant bicycle safety improvements and as a result, a likely reduction of bicycle related injuries.
- **Benefit 6: Facility Improvements – Walking**
  - The Project will improve sidewalks and therefore improve the quality or comfort of journeys made by pedestrians.
- **Benefit 7: Facility Improvements – Cycling**

    - The Project will install new bicycle facilities and therefore improve the quality or comfort of journeys made by cyclists.
- **Disbenefit 8: Value of Travel Time**
    - The Project will lead to an increase in travel delays.
- **Benefit 9: Mortality Reduction Benefits — Walking**
    - The Project will encourage more walking which can lead to a reduction in mortality risks for pedestrians.
- **Benefit 10: Mortality Reduction Benefits — Cycling**
    - The Project will encourage more cycling which can lead to a reduction in mortality risks for bicyclists.
- **Benefit 11: Congestion Externalities Reduction**
    - The Project will include new active transportation facilities, therefore encourage active transportation, which reduces automobile usage and results in reduced congestion externalities.
- **Benefit 12: Emissions Reduction – Walking**
    - The Project will include upgraded sidewalks and therefore encourage active transportation, which reduces automobile usage and therefore a reduction of emissions from automobile usage.
- **Benefit 13: Emissions Reduction – Cycling**
    - The Project will include new bicycle facilities and therefore encourage active transportation, which reduces automobile usage and therefore a reduction of emissions from automobile usage.

The baseline (No-Build) and Build methodology and calculations for each benefit are contained within this technical memorandum, supported by the BCA Excel Workbook. The benefits are quantified and monetized for the BCA.

Benefits and costs in real dollars and discounted real dollars are shown in the following table. Real dollars, also known as inflation-free dollars or constant dollars, stands for dollars that are netted out the effect of inflation by using a common base year. Discounting is made to account for the time value of money. It means benefits and costs that occur sooner rather than later are valued more, and there is thus a cost associated with diverting the resources needed for an investment from other productive uses in the future.[2] Future streams of benefits and costs will be expressed in the same present value terms after discounting.

2 Federal Highway Administration. Benefit-Cost Analysis Guidance for Discretionary Grant Programs

The benefit-cost ratio is 1.9 in 2021 real dollars and when discounted at a 7% discount rate, the benefit-cost ratio is 1.0. The 2021 real dollar NPV is $46,366,000 and when discounted at 7%, $987,000.

Table 3. BCA Summary

Scenario	$2021 Real Dollars	$2021 Real Dollars 7% Discount
Benefits	$95,802,000	$37,677,000
Costs	$49,333,000	$36,699,000
BCA	1.9	1.0
NPV	$46,470,000	$978,000

Table 4 summarizes the Project benefits.

Table 4. Project Benefits Summary

Benefit	Current Status/Baseline and Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts	$2021 Monetized Value	$2021 Real Dollars 7% Discount Rate
Benefit 1: Remaining Useful Life of Asset	The current asset has 0% remaining useful life	Replace infrastructure within public right-of-way	Extend useful life	$27,341,000	$5,038,000
Benefit 2: State of Good Repair	Ongoing expensive maintenance of roadway pavement	Low maintenance required of new facility through the planning horizon	Maintenance cost savings	$8,888,000	$3,678,000
Benefits 3, 4, and 5: Safety Benefits	Outdated design, disproportionally higher crash rates	Safety improvement resulting in reduction in traffic crashes	Reduced crashes resulting in reduced fatalities and injuries	$63,866,000	$30,432,000
Benefits 6 and 7: Facility Improvements	The current facilities are not conductive for active transportation	Improvements to the current facilities will improve the quality or comfort of journeys	Improved comfort for active transportation	$2,057,000	$784,000
Benefit 8: Value of Travel Time	The current facilities lead to significant travel delay	Improvements to the current facilities will increase delay	Travel time increase	-$10,949,00	-$4,016,000
Benefits 9 and 10: Mortality Reduction Benefits	Roadway is not conducive for active transportation	New and improved active transportation facilities will encourage more walking and cycling	Reduced mortality risks associated with increased walking and cycling	$4,317,000	$1,646,000

Benefit	Current Status/Baseline and Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts	$2021 Monetized Value	$2021 Real Dollars 7% Discount Rate
Benefit 11: Congestion Externalities Reduction	Roadway is not conducive for active transportation	New and improved facilities will encourage more walking and cycling	Reduced congestion externalities	$245,000	$93,000
Benefits 12 and 13: Emissions Reduction	The current facilities are not conductive for active transportation	Improvements to the existing facilities will induce demand for walking and cycling	Reduced emission derived from modal shift from driving personal vehicles to walking and biking	$37,000	$23,000
			Totals	**$95,802,000**	**$37,677,000**

Foundations to Benefit / Cost Analysis

The following methodologies and/or general assumptions are used to quantify the benefits for the Project.

Real Dollars & Discount Rate

All monetized values in both benefit and cost equations within the analysis have been converted to a base year (real dollars) of 2021. Cost elements that were expended or derived from cost estimates in prior years were inflated using the inflation adjustment values found in Table A-7 in the 2023 USDOT BCA Guidance for Discretionary Grant Programs.[1] The inflation factors were removed for non-capital and operational cost elements (e.g., safety monetization factor) that occurred in 2021.

The OMB Circular A-94 provides guidance on discount rates. As a default position, OMB Circular A-94 states that a discount rate of 7% should be used as a base-case for regulatory analysis. The 7% rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital. A 7% discount rate was applied to all 2021 real dollar monetized costs and benefits.

Planning, design, environmental and capital costs

The costs for the Project in year of expenditure, or nominal dollars, is $54,851,000. The annual inflation factor of 2.44% applied to the projected costs (nominal $), was discounted from the year of expenditure to reflect the real $ in year 2021. The 2.44% inflation factor is derived from the 2003 to 2021 inflation adjustment values found in Table A-7 in the 2023 USDOT BCA Guide. The total project cost in 2021 real dollars is

$49,333,000. These costs are discounted 7% from the expenditure year to year 2021. The total year 2021 real discounted costs are $36,699,000.

Planning Horizon

The 20-year planning horizon is from 2026 to 2046 and discounted at 7% to 2021 dollars. The Project is assumed to open in 2026; thus, most benefits are generally quantified for a 20-year period, from 2026 once the facility is open for users.

No-Build Scenario

The No-Build Scenario assumes that roadway improvements will only consist of minimal planned improvements to the project corridor within the No-Build Scenario.

Benefit 1: Remaining Useful Life of Asset

No-Build Scenario

The roadway in the Project corridor will need to be repaired throughout the planning horizon.

Build Scenario

The Project will be designed and constructed for a useful life of 50 years.[3]

Methodology/Summary

The residual life benefit assumes there will be 60% of the Project life remaining at the end of the planning horizon. The residual life benefit only captures 60% of the construction cost of the Project. Using Equation 1, the remaining useful life for the Project is calculated.

Equation 1. Useful Life Methodology

Useful Life = Construction Costs * 60%

Accumulated benefits for the 20-year horizon are quantified and discounted at a 7% rate, shown in Table 5.

Table 5. Useful Life Benefit

Scenario	Monetized Values
No-Build Benefit	$0
Build Benefit	$27,341,000
Net Benefit	**$27,341,000**

3 City of Houston (2022). Public Works Infrastructure Design Manual. Retrieved August 2022 from https://www.houstonpermittingcenter.org/news-events/2021-infrastructure-design-manual-announcement

Net Benefit Discounted @ 7% to $2021	**$5,038,000**

Benefit 2: State of Good Repair

Maintenance and user costs associated with the condition of a roadway's surface are significant factors in the decision to continue with the current pavement or to replace it. The capital expenditure required for a reconstruction project may make economic sense if it saves money over the planning horizon. Demonstrating a roadway's current surface condition, or state of good repair (SOGR), and projecting the costs and benefits for alternative maintenance strategies will provide the information needed to make this decision.

No-Build Scenario

Continue maintenance strategy through remaining life of facility.

Build Scenario

The existing pavement along the project corridor will be replaced with new concrete pavement.

Methodology

This section summarizes the methodology and results of this analysis.

Life Cycle Cost Analysis Methodology

The evaluation for SOGR uses a Life Cycle Cost Analysis (LCCA) model adapted to the scope of this project to determine the more cost-effective of the No-Build and Build Scenarios.[4] The primary purpose of this method is to compare the costs of reconstruction to those of continued maintenance of the existing roadway surface. The focus of the analysis is pavement condition and does not include costs associated with drainage, traffic management, or other non-vehicular support facilities. The analyzed costs include agency costs due to reconstruction or repair, user costs due to construction zone time delays, and operation and upkeep of vehicles used on the roadway throughout its life cycle. The life cycles for asphalt and concrete pavement are

4 Federal Highway Administration. Life-Cycle Cost Analysis. Retrieved August 2022 at https://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm.

assumed to be 25 years and 50 years, respectively. The phasing of the 25-year asphalt life cycle is shown in Figure 1.[5,6]

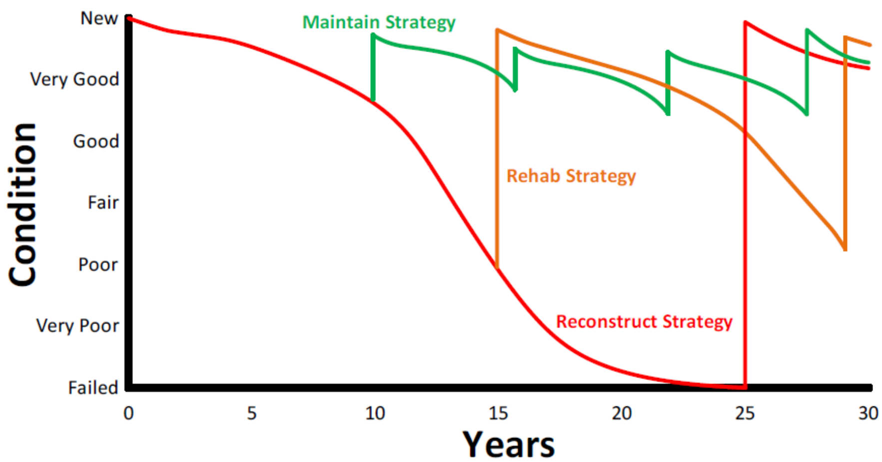

Figure 1. Pavement Life Cycle Curve

The key assumption is that if the proposed Project is not implemented (No-Build Scenario), the City of Houston will follow a maintenance strategy that includes annual routine maintenance and periodic rehabilitation for the project corridor. Conversely, the Build Scenario, in which the roadway is rebuilt and thus brand new, would result in no maintenance or rehabilitation requirements within the planning horizon. The key roadway characteristics related to the analysis are summarized in Table 6.

Table 6. Telephone Road Characteristics

Segment	Class	Pavement	Length (ft)	Lanes	Lane-miles	Average Daily Traffic (2022)	Truck %
between IH-610 EB Frontage Road and McHenry Street	Arterial	Asphalt Overlay	3168	5	3.00	18,746	3.25%
between McHenry Street and Reveille Street	Arterial	Asphalt Overlay	5280	6	6.00	18,746	3.25%

Maintenance – Asphalt Pavement

An assessment of the pavement's current SOGR determines where the roadway is on its life cycle curve. The life cycle curve is composed of phases established by the TxDOT

5 Texas Department of Transportation. Transportation Asset Management Plan, p. 53. Retrieved August 2022 from https://www.nctcog.org/nctcg/media/Transportation/DocsMaps/Data/Performance/TxDOT-Initial-Transportation-Asset-Management-Plan.pdf
6 City of Houston (2018). Public Works Infrastructure Design Manual, p. 10-6. Retrieved June 2019 from https://edocs.publicworks.houstontx.gov/documents/design_manuals/idm.pdf

TAMP and assumes a 25-year life for asphalt pavement. By modeling the deterioration of pavement over time due to environmental and traffic factors, the phases establish timings for maintenance requirements and effects on user vehicle operating costs for the No-Build Scenario.

The pavement's condition declines gradually in its first four years, but then quickly deteriorates to an unacceptable state. Any rehabilitation or maintenance strategy can reset the pavement's life cycle to a certain extent. Based on information from the City of Houston Public Works, and verified by site visits, the corridor is mostly in the early phase of its service life. Most of Telephone Road is in good condition.

A critical planning factor for maintenance operations is that the cost of repairs increases as the reliability of pavement decreases over the service life.[7] Essentially, newer pavement requires less maintenance than older, more deteriorated pavement to maintain acceptable levels of service. To approximate the increasing probabilities of portions of each roadway requiring repairs and the effects on maintenance costs, this analysis used approximate failure rate factors as a multiplier of the annual maintenance costs incurred by the City of Houston. The City of Houston FY2021 expenditures on street and bridge maintenance is over $100 million, which covers about 16,600 lane-miles of roadways, according to the Department of Public Works.[8] This analysis used the average expenditure from these totals ($6,135 per lane-mile), the lane-miles of each roadway, and the failure rate factor to develop estimates of annual maintenance costs by life cycle phase based on condition, shown in Table 7.

Table 7. Annual Pavement Maintenance Costs by Life Cycle Phase

Phase	Percent of Life	Failure Rate Factor	Cost
New	24%	0.00	$0
Very Good	40%	0.00	$0
Good	52%	0.25	$13,803
Fair	64%	1.00	$55,211
Poor	80%	1.50	$82,816
Very Poor	100%	3.00	$165,633

Rehabilitation, for this analysis, consists of asphalt mill and overlay conducted at select intervals in addition to routine annual repairs to maintain the structural integrity of the roadway. The expected result of this strategy is the extension of the service life of the

7 Federal Highway Administration (2013). Reformulated Pavement Remaining Service Life Framework, p. 43-49. Retrieved August 2022 from https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/13038/13038.pdf
8 City of Houston Fiscal Year Operating Budgets, Retrieved in August 2022 from https://www.houstontx.gov/budget/

roadway by approximately 10 years for asphalt.[9] Based on each pavement's life cycle, iterations of systematic repairs will be required over the next 20 years.

Table **8** shows the schedule for rehabilitation under the No-Build Scenario.

Table 8. Rehabilitation Cycle

Roadway	Pavement	1st Rehab	2nd Rehab	3rd Rehab	4th Rehab
Telephone Road	Mill & Overlay	2026	2035	2044	2053

For simplicity, this analysis assumes the rehabilitation of the entire length of the Project within the stated limits would be accomplished within time periods noted above. Similarly, it is assumed all failures of pavement within a certain life cycle phase occur all at once and the replacement costs may be captured as discrete projects. This analysis also assumes that unforeseen pavement failures that affect daily traffic are addressed as needed through annual maintenance and there would be residual life of the last major rehabilitation within the planning horizon.

The rehabilitation of the asphalt surfaces of the Project is projected in this analysis to occur in 10-year increments. According to TxDOT's Average Low Bid Unit Prices, the cost for mill and overlay is $11,500 per lane-mile in 2021. The total cost of mill and overlay can be calculated using Equation 2.

Equation 2. Cost of Asphalt Pavement with Mill & Overlay

Mill & Overlay Cost = $11,500 * L * M
L = number of lanes M = roadway (project limits) length in miles

Given the roadway characteristics and rehabilitation schedule, the total rehabilitation costs of the asphalt pavement under the No-Build Scenario are listed in in Table 9.

Table 9. Asphalt Pavement Mill and Overlay Costs

Roadway	Lane-miles	1st Mill & Overlay	2nd Mill & Overlay	3rd Mill & Overlay	Residual Life Remaining	Total Cost
Telephone Road	9.00	$389,000	$484,000	$601,000	-$473,000	$1,001,000

9 City of Houston Report to TTI Committee. Retrieved August 2022 from https://www.houstontx.gov/council/committees/tti/20140513/Maintaining_Houston_Streets.pdf

The preferred alternative minimizes total maintenance costs over the planning horizon. As presented above, annual maintenance and scheduled rehabilitation for the existing pavements create a cost, or disbenefit, to the City of Houston for the No-Build Scenario. The Build Scenario presents an opportunity to avoid most of that financial burden. The proposed construction calls for new pavement would not require maintenance or rehabilitation for the remainder of the planning horizon; thus, the only rehabilitation costs are those incurred prior to project implementation.

Table 10 summarizes the maintenance and rehabilitation costs for each scenario.

Table 10. Summary of Maintenance & Rehabilitation Costs

Roadway	No-Build Scenario			Build Scenario		
	Annual Maintenance	Scheduled Rehab	Roadway Subtotal	Annual Maintenance	Scheduled Rehab	Roadway Subtotal
Telephone Road	$703,000	$1,001,000	$1,704,000	$25,000	0	$25,000

User Costs

As pavement conditions worsen over the life of the roadway, the cost to the community to maintain vehicles operated on the roads also increases.[10] For planning purposes, this analysis assumes that qualitative assessments of pavement condition are correlated with established roughness indices and thus may be used to estimate its impact on vehicle operating costs. The study referenced by this analysis established baseline costs in terms of cents per mile for passenger and commercial vehicles on new pavement, as well as cost factors for each of five roughness index values, listed in Table 11.

Table 11. Vehicle Operating Costs in ¢/mile (inflated to $2021)

Vehicle Class	Road Class	Pavement Roughness Index / TxDOT Phase					
		Baseline	Adjustment Factors (multiplied by baseline for cost per mile)				
		Cents Per Mile ($2021)	2 Very Good	3 Good	4 Fair	5 Poor	6 Very Poor
Very Poor	Collector	19.8	1.02	1.03	1.07	1.15	1.25
Poor	Arterial	24.7	1.02	1.03	1.07	1.15	1.24

10 National Academy of Sciences, Engineering, and Medicine (2012). Estimating the Effects of Pavement Condition on Vehicle Operating Costs, p. 40-50.. Washington, D.C.: The National Academies Press. https://doi.org/10.17226/22808

Fair	Highway	32.4	1.01	1.02	1.06	1.14	1.22
Good Very Good	Collector	52.1	1.02	1.03	1.07	1.13	1.21
	Arterial	80.3	1.01	1.02	1.05	1.11	1.18
	Highway	114.0	1.01	1.02	1.04	1.09	1.15

When correlated with the five TxDOT pavement condition phases, these factors can be applied to forecast vehicle operating costs that the public bears to the planning horizon. Several variables are required to complete this analysis, including current condition assessments of the roadways, H-GAC traffic model data for volume on each road type over time, and TxDOT traffic count data for commercial vehicle (truck) percentage; all of which were provided earlier in this section.

The difference between the costs due to the condition of the pavement during any year within the planning horizon and the baseline costs for new pavement is the disbenefit to the community from the state of good (or bad) repair. This analysis accumulated the year-over-year car and truck cost differentials to compare the total disbenefit due to vehicle operating costs for No-Build and Build Scenarios. Table 12 shows the total operating costs for each scenario.

Table 12. Summary of Vehicle Operating Costs (inflated to $2021)

Roadway	No-Build Scenario			Build Scenario		
	Car	Truck	Total Vehicle	Car	Truck	Total Vehicle
Telephone Road	$798,000	$61,000	$859,000	$187,000	$11,000	$198,000

During reconstruction (Build Scenario) or maintenance treatment cycles (No-Build Scenario), users incur costs due to delays. They may need to reduce speed or wait in a queue. For the purposes of this analysis, overall speed through work zones is assumed to drop by 25%. Repairs are assumed to take approximately 240 days per mile for reconstruction and 120 days per mile for the maintenance treatment cycles. Per USDOT guidance, the value of travel time is $19.24 per hour per person and vehicle occupancy is 1.65 persons per vehicle. Since repair projects occur in multiple years, this analysis adjusted traffic volume used to calculate cost based on growth rate to the year of repair. Equation 3 shows the total user cost due to delays during the construction period is equivalent to time lost to slower overall speeds through the work zones.

Equation 3. User (Delay) Cost

User (Delay) Cost = AADT · 1.65 * $19.24 * D * 0.75(T)
AADT = Average Annual Daily Traffic (number vehicles per day) D = construction work zone duration (workdays)

T = Normal travel time (hours) through zone = Lane-miles / Speed Limit (mph)

The analysis tabulated AADT for each year in the planning horizon by factoring the growth rate inferred from results of forecast year traffic volumes from the TxDOT. Assuming linear growth, annual traffic volume can be calculated using Equation 4.

Equation 4. Traffic Volume

Traffic Volume = AADTc * (1+ X) * N
$AADT_c$ = Current year's volume X = Annual growth rate N = Number of years to which volume is being forecasted

The results of the user delay costs are shown in Table 13.

Table 13. Summary User Delay Costs

Scenario	Costs
No-Build Cost	$6,547,000
Build Cost	$3,690,000

SOGR Benefit Summary

The preferred scenario from the perspective of SOGR minimizes costs due to maintenance and user costs. Overall, the Build Scenario is preferable to No-Build on the merits of savings in each of the three categories covered in this section: life cycle costs, maintenance costs, and user costs. Accumulated benefits for the analysis period are quantified and discounted at a 7% rate, shown in Table 14.

Table 14. State of Good Repair Benefit

Scenario	Monetized Value
No-Build Cost	$9,111,000
Build Cost	$223,000
Net Benefit	**$8,888,000**
Net Benefit Discounted @ 7% to $2021	**$3,678,000**

Benefits 3, 4 and 5: Safety Benefits

The Project will improve safety along the Project corridor by reducing the number of crashes. Benefits can be derived from the projected reduction in the number of crashes and property damage incurred.

No-Build Scenario

The corridor would incur no safety improvements and would continue to be an unsafe urban corridor in Houston, Texas.

Build Scenario

The Project would experience significant safety improvements, resulting in fewer traffic accidents.

Methodology/Summary

The analysis uses the average number of crashes by type over the last 5 years (2018-2022) from TxDOT Crash Record Information System (CRIS) database. The appropriate reduction factor was given by TxDOT based on the 2022 TxDOT Highway Safety Improvement Program (HSIP) work codes, and the damages avoided are quantified.[11] Accumulated benefits are totaled and discounted at a 7% rate.

To evaluate the existing conditions on the Project corridor, crash records were obtained from TxDOT CRIS database for years 2018-2022. TxDOT uses the KABCO Scale in the CRIS database, which uses law enforcement data and rates traffic crash injuries. The monetary value of potential safety improvements used in the BCA that are provided by the 2023 USDOT BCA Guide are listed in Table 15. The methodology uses the reduction in crashes associated with each roadway improvement, as identified in HSIP.

For all project types, when the number of crashes decreases with safety improvements, benefits also accrue from reduced property damage. This methodology is documented in the 2023 USDOT BCA Guide. The guide values each crash with only property damage at $8,600 in damages ($2021).

Table 15. Monetary Value of Fatalities and Injuries from Traffic Accidents

KABCO Level	Monetized Value ($2021)
O – No Injury	$4,000
C – Possible Injury	$78,500
B – Non-incapacitating	$153,700
A – Incapacitating	$564,300
K – Killed	$11,800,000
U – Injured (Severity Unknown)	$213,900
# Accidents Reported (Unknown if Injured)	$162,600

11 Texas Department of Transportation (2022). Highway Safety Improvement Manual. Retrieved August 2022 from https://www.txdot.gov/inside-txdot/forms-publications/publications/highway-safety.html

HSIP Work Codes correspond to different enhancements (e.g., improve traffic signals, install raised medians, install pavement markings). TxDOT has a work code table that provides associated definitions, reduction factors, and preventable crash codes. Preventable crashes are those with defined characteristics that may be affected by the proposed improvement as described by the work code. The codes correspond to numeric codes assigned in CRIS to the indicated variable. Information is collected from law enforcement crash reports and converted into a coded format that corresponds to the work code table.

A crash can only be assigned to one work code. If multiple work codes are applicable to one crash, the work code with the highest crash reduction rate will be assigned to that crash. For the Project, crashes from 2018-2022 were assigned to codes listed in Figure 2.

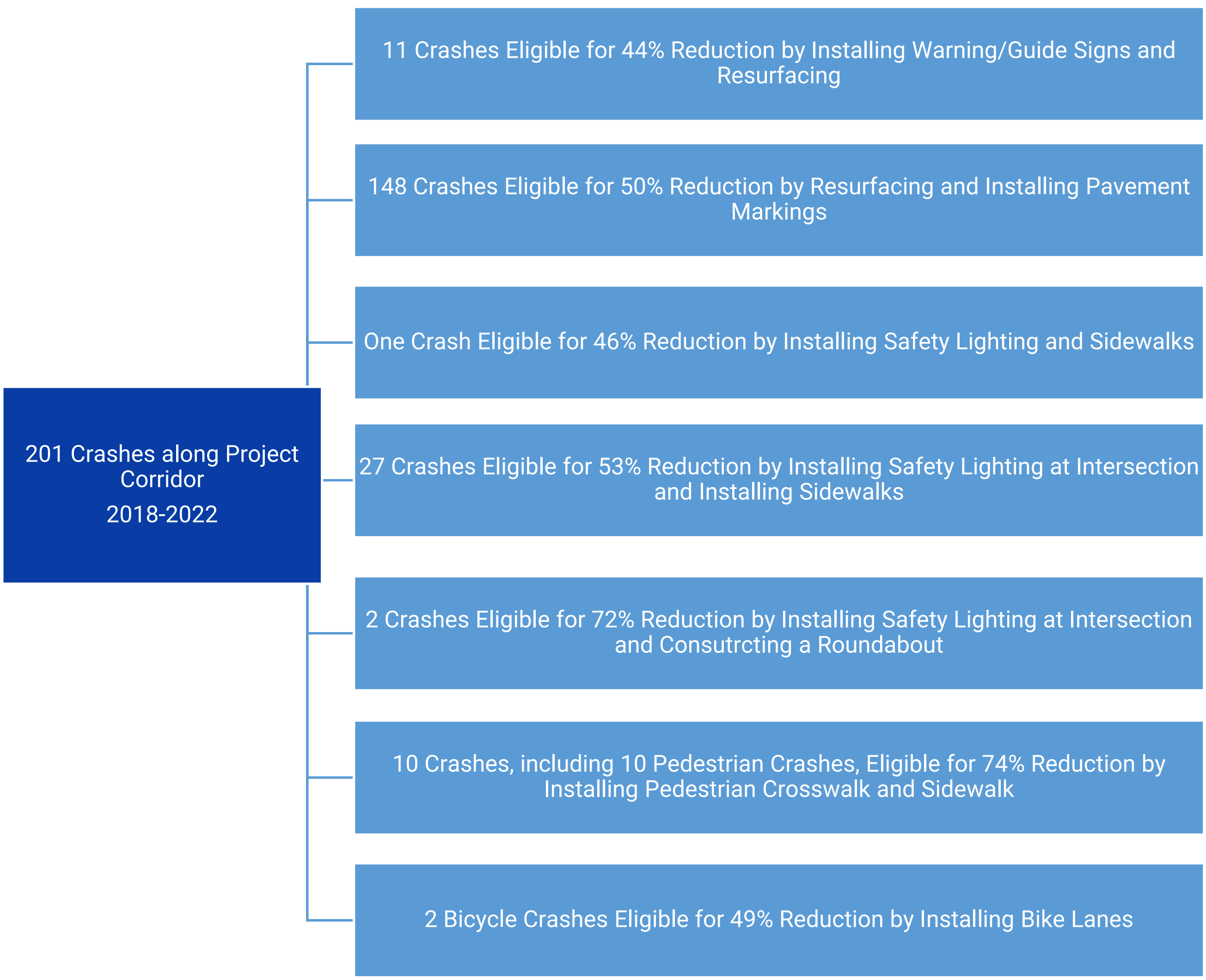

Figure 2. Traffic Crashes and HSIP Work Codes

Work codes based on crashes that can be avoided are described in the following tables.

Table 16. Crash Reduction Factor – Install Warning/Guide Signs, Resurfacing

Work Code 101, 303: Install Warning/Guide Signs, Resurfacing	
Definition	Provide advance signing for unusual or unexpected roadway features where no signing existed previously; Provide a new roadway surface to increase pavement skid numbers on all the lanes.
Reduction Factor	44%
Service Life (Years)	10
Maintenance Cost	N/A
Preventable Crashes	(Vehicle Movements/Manner of Collision = 20-22 or 30) OR (Roadway Related = 2, 3 or 4) OR Surface Condition = 2, 5, 6, or 9 (Skid Value must be less than 20)

Table 17. Crash Reduction Factor – Resurfacing, Install Pavement Markings

Work Code 303, 401: Resurfacing, Install Pavement Markings	
Definition	Improve existing intersection signals to current design standards; Install a roadway divider using barrier curb.
Reduction Factor	51%
Service Life (Years)	20
Maintenance Cost	(Intersection Related = 1 or 2) AND [(Vehicle Movements/Manner of Collision =10-39) OR (First Harmful Event = 1 or 5)] OR [(Part of Roadway No. 1 Involved = 1) AND (Vehicle Movements/Manner of Collision = 10, 14, 20-22, 24, 26, 28-30, 34, 36, or 38)]

Table 18. Crash Reduction Factor - Safety Lighting, Install Sidewalks

Work Code 304, 407: Safety Lighting, Install Sidewalks	
Definition	Provide roadway lighting, either partial or continuous, where either none existed previously or major improvements are being made; Install sidewalks where none existed previously.
Reduction Factor	46%
Service Life (Years)	15
Maintenance Cost	N/A
Preventable Crashes	Light Condition = 3, 4 or 6 OR First Harmful Event = 1 or 5

Table 19. Crash Reduction Factor – Safety Lighting at Intersection, Install Sidewalks

Work Code 305, 407: Safety Lighting at Intersection, Install Sidewalks	
Definition	Install lighting at an intersection where either none existed previously or major improvements are proposed; Install sidewalks where none existed previously.
Reduction Factor	53%
Service Life (Years)	15
Maintenance Cost	N/A

Preventable Crashes	Light Condition = 3, 4 or 6 AND Intersection Related = 1 or 2 OR First Harmful Event = 1 or 5

Table 20. Crash Reduction Factor – Safety Lighting at Intersection, Construct a Roundabout

Work Code 305, 547: Safety Lighting at Intersection, Construct a Roundabout	
Definition	Install lighting at an intersection where either none existed previously or major improvements are proposed; Convert an existing intersection to a single lane roundabout design
Reduction Factor	72%
Service Life (Years)	15
Maintenance Cost	N/A
Preventable Crashes	Light Condition = 3, 4 or 6 AND Intersection Related = 1 or 2 OR Intersection Related = 1 or 2

Table 21. Crash Reduction Factor – Install Pedestrian Crosswalk, Install Sidewalks

Work Code 403, 407: Install Pedestrian Crosswalk, Install Sidewalks	
Definition	Place pedestrian crosswalk markings where none existed previously. Install sidewalks where none existed previously.
Reduction Factor	74%
Service Life (Years)	10
Maintenance Cost	N/A
Preventable Crashes	First Harmful Event = 1 OR First Harmful Event = 1 or 5

Table 22. Crash Reduction Factor – Install Bike Lanes[12]

Work Code: Install Bike Lanes	
Definition	Bicycle lane on Urban 4-lane undivided collectors and local roads
Reduction Factor	49%
Service Life (Years)	20
Maintenance Cost	N/A
Preventable Crashes	First Harmful Event = 5

Using the average crash data from 2018-2022 available in the CRIS dataset, eligible crashes are reduced by the reduction factor above and monetized based on the USDOT recommended values in Table 15. Accumulated benefits for the specified service life are quantified up and discounted at a 7% rate, shown in the following tables.

Table 23. Motorist Safety Benefits

Scenario	Monetized Value
No-Build Cost	$85,466,000
Build Cost	$45,284,000

[12] U.S. Department of Transportation Federal Highway Administration. (2023). Bicycle Lanes. Retrieved from https://highways.dot.gov/safety/proven-safety-countermeasures/bicycle-lanes

Net Benefit	**$40,182,000**
Net Benefit Discounted @ 7% to $2021	**$18,177,000**

Table 24. Pedestrian Safety Benefits

Scenario	Monetized Value
No-Build Cost	$31,337,000
Build Cost	$8,148,000
Net Benefit	**$23,190,000**
Net Benefit Discounted @ 7% to $2021	**$12,060,000**

Table 25. Bicycle Safety Benefits

Scenario	Monetized Value
No-Build Cost	$1,009,000
Build Cost	$515,000
Net Benefit	**$494,000**
Net Benefit Discounted @ 7% to $2021	**$195,000**

Benefits 6 and 7: Facility Improvement Benefits

Improvements to pedestrian, cycling, transit facilities, and transit vehicles often provide amenities that can improve the quality and comfort of journeys made by active transportation (e.g., cyclists and pedestrians) and public transportation users. The improvements will not only benefit the existing users, but also encourage more people walking, biking, and using public transit. The 2023 USDOT BCA Guidance provides recommended monetized values for facility improvement benefits based on the research of revealed preferences of system users. For additional users attracted to the improved facilities, the value of the benefits they receive is at one-half the product of the value and the difference in volumes between the Build and No-Build Scenarios. The number of existing and mode-shift new walking and biking trips are obtained from the H-GAC's Bike-Ped Commuter Analysis[13].

No-Build Scenario

The current condition of the existing facilities is not conductive for walking or cycling.

Build Scenario

The Project will improve the active transportation facilities.

[13] Source: H-GAC Regional Data Hub (2023). Activity-Connectivity Explorer. Retrieved from https://datalab.h-gac.com/ace/

Methodology/Summary

This section summarizes the methodology and results of the analysis for facility improvement benefits.

Pedestrian Facility Improvements

The 2023 USDOT BCA Guidance points out that traffic speeds and volumes along key pedestrian corridors, as well as elevation gains and width of sidewalks, can directly affects the comfort, convenience, and safety of the facility for pedestrian use.

Using revealed preference studies, the recommended value per person-mile walked on an expanded sidewalk is $0.11 for each foot of added width. For the mile-based benefits, the estimated value per pedestrian is capped at 0.86 miles, which is the average length of a walking trip in the 2017 National Household Travel Survey. The monetized benefits for expansions are appliable for sidewalks up to approximately 31 feet. For additional users attracted to the improved facilities, the value of the benefits they receive is at one-half the product of the value and the difference in volumes between the Build and No-Build Scenarios The benefits of improved pedestrian facilities are calculated using Equation 5.

Equation 5. Pedestrian Facility Improvement Benefits – Sidewalk Expansion

Sidewalk Expansion Benefit = $0.11 * Added Width (foot) * (Number of Existing Walking Trips + ½ New Walking Trips) * Trip Length
Trip Length = Proposed Length of Expanded Sidewalk or 0.86 Miles (whichever is smaller)

Accumulated benefits for the 20-year horizon are quantified and discounted at a 7% rate, presented in Table 26.

Table 26. Pedestrian Facility Improvement Benefit

Scenario	Monetized Value
No-Build Cost	$0
Build Cost	$169,000
Net Benefit	**$169,000**
Net Benefit Discounted @ 7% to $2021	**$64,000**

Bicycle Facility Improvements

The 2023 USDOT BCA Guidance suggests that cycling facilities can improve journey quality and comfort for cyclists, in addition to any travel time savings they provide. The recommended monetized value per cycling mile for various cycling facility improvements are listed in Table 27. The Project will construct new dedicated/separated bike lanes. The value of Dedicated Cycling Lane/Separated Cycle Track is used for calculating the improvement benefit.

Table 27. Cycling Facility Improvement Revealed Preference Values

Facility Type	Recommended Value per Cycling Mile (2021 $)
Cycling Path with At-Grade Crossings	$1.42
Cycling path with no At-Grade Crossings	$1.78
Dedicated Cycling Lane	**$1.69**
Cycling Boulevard/"Sharrow"	$0.26
Separated Cycle Track	**$1.69**

The benefit of cycling facility improvements is calculated using Equation 6. The average length of a cycling trip in the 2017 National Household Travel Survey is 2.38 miles. According to 2023 USDOT BCA Guidance, if the cycling facility length is less than 2.38 miles, then the trip length per cyclist is equal to the facility length; however, if the cycling facility is longer than 2.38 miles, the assumption that all cyclists travel the full distance of a proposed facility cannot be made. For additional users attracted to the improved facilities, the value of the benefits they receive is at one-half the product of the value and the difference in volumes between the Build and No-Build Scenarios.

Equation 6. Cycling Facility Improvement Benefit

Cycling Facility Improvement Benefit = Value per Cycling Mile * (Number of Existing Cycling Trips + ½ New Cycling Trips) * Trip Length
Trip Length = Proposed Cycling Facility Length or 2.38 Miles (whichever is smaller)

Accumulated benefits for the 20-year horizon are quantified and discounted at a 7% rate, presented in the following table.

Table 28. Cycling Facility Improvement Benefit

Scenario	Monetized Value
No-Build Benefit	$0
Build Benefit	$1,888,000
Net Benefit	**$1,888,000**
Net Benefit Discounted @ 7% to $2021	**$720,000**

Disbenefit 8: Value of Travel Time

No-Build Scenario

The roadway would increase in traffic volumes and congestion delays throughout the planning horizon.

Build Scenario

The Project will improve the roadway facilities but also increase travel times for roadway users of this corridor.

Methodology/Summary

The impact of a project on congestion can be measured through the value of travel time (VoTT) on the network. Travel time has a direct relationship with overall network congestion. The more congested a roadway or network is, the longer the travel time is, thereby increasing person hours traveled. The methodology for determining congestion benefits analyzes delay reduction at intersections with a micro-level model during the AM and PM peak hour for driving. This method requires collecting the current traffic counts along the affected roadways and project the future volume under the Build and No-build scenarios. The analysis shows the operational impacts of the proposed Project, which includes intersection delay. The modeling results suggest that the Project will increase average vehicle delays at the intersections. Therefore, the Project will increase travel time of motor vehicles.

The traffic impact analysis provides the average delay caused by the Project, while the 2023 USDOT BCA Guidance provides recommended hourly values ($2021) of travel time savings for occupants of passenger vehicles ($18.80/person-hour and 1.67 persons per vehicle) and for commercial vehicle operators ($32.40/person-hour). A separate value is provided for reductions in other components or aspects of travel time, including walking, cycling, waiting time, transfer time, and time spent standing in a crowded transit vehicle ($34.00/person-hour). Using Equation 7, the users' value of time, including driving, walking, and taking public transit, for the Project is calculated.

Equation 7. Value of Travel Time

Travel Time Savings = Annual Person-Hour Saved * VoTT
Annual Person-Hour Saved for Year N = VHT for Project build year*$(1.7\%+x\%)^n$ x% is assumed to be the annual growth rate

Accumulated benefits within the planning horizon are quantified and discounted at a 7% rate, presented in Table 29.

Table 29. Summary Value of Travel Time Costs

Scenario	Monetized Value
No-Build Cost	$300,214,000
Build Cost	$311,163,000
Net Benefit	-$10,949,000

Net Benefit Discounted @ 7% to $2021	-$4,016,000

Benefits 9 and 10: Mortality Reduction Benefits

Active transportation modes such as walking and cycling can help improve cardiovascular health and lead to other positive outcomes for users. Adding or upgrading cycling or pedestrian facilities can convert users from inactive transportation modes to active transportation modes. A key health outcome from increased physical activity is a reduction in mortality risks for those users that are converted to active transportation modes from inactive modes. The number of existing and mode-shift new walking and biking trips are obtained from the H-GAC's Bike-Ped Commuter Analysis[14].

No-Build Scenario

The existing sidewalks are in disrepair and there is a lack of bicycle facilities.

Build Scenario

The Project will rehabilitate and install new sidewalks, as well as construct dedicated/separated bike lanes.

Methodology

Mortality Reduction - Walking

To monetize the reduction in mortality risks associated with increased walking, the 2023 USDOT BCA Guide recommends $7.20 ($2021) per induced walking trip. This is based on the following factors: an assumed average walking speed of 3.2 miles per hour, an assumed average age of the relevant age range (20-74 years) of 45, a corresponding baseline mortality risk of 267.1 per 100,000, an annual risk reduction of 8.6 percent per daily mile walked, and an average walking trip distance of 0.86 miles. This monetized value can only be applied to trips induced from non-active transportation modes within the relevant age range. A general assumption of 68% of overall induced trips falling into the walking age range (20-74 years), assuming a distribution matching the national average, is applied in the absence of more localized data on the proportion of the expected users falling into the age range. Equation 8 is used to estimate the mortality reduction benefits of induced walking trips.

Equation 8. Mortality Reduction Benefits - Walking

Mortality Reduction Benefits = Number of New Walking Trips Induced from Non-Active Transportation Modes * 68% * $7.20

[14] Source: H-GAC Regional Data Hub (2023). Activity-Connectivity Explorer. Retrieved from https://datalab.h-gac.com/ace/

The accumulated benefits of mortality reduction benefits for the analysis period are quantified and discounted at a 7% rate, presented in Table 30.

Table 30. Mortality Reduction Benefit - Walking

Scenario	Monetized Value
No-Build Cost	$0
Build Cost	$720,000
Net Benefit	**$720,000**
Net Benefit Discounted @ 7% to $2021	**$275,000**

Mortality Reduction - Cycling

The 2023 USDOT BCA Guide recommends $6.42 ($2021) per induced cycling trip to monetize reduced mortality risks associated with increased cycling. It is based on an assumed average cycling speed of 9.8 miles per hour, an assumed average age of the relevant age range (20-64 years) of 42, a corresponding baseline mortality risk of 217.9 per 100,000, an annual risk reduction of 4.3 percent per daily mile cycled, and an average cycling trip distance of 2.38 miles. This monetization value can only be applied to trips induced from non-active transportation modes within the relevant age ranges. A general assumption of 59% of overall induced trips falling into the cycling age range (20-64 years), assuming a distribution matching the national average, is applied in the absence of more localized data on the proportion of the expected users falling into the age range. Equation 9 is used to estimate the mortality reduction benefits of induced cycling trips.

Equation 9. Mortality Reduction Benefits – Cycling

Mortality Reduction Benefits = Number of New Cycling Trips Induced from Non-Active Transportation Modes * 59% * $6.42

The accumulated benefits of mortality reduction benefits for the analysis period are quantified and discounted at a 7% rate, presented in Table 31.

Table 31. Mortality Reduction Benefit - Cycling

Scenario	Monetized Value
No-Build Cost	$0
Build Cost	$3,597,000
Net Benefit	**$3,597,000**
Net Benefit Discounted @ 7% to $2021	**$1,371,000**

Benefit 11: Congestion Externalities Reduction

Reductions in external costs from modal diversion may represent a source of potential benefits beyond those experienced directly by users of an improved facility or service. The operation of automobiles can cause negative impacts such as delays to other vehicles during congested travel conditions, increased external crash costs, emissions of air pollutants, noise pollution, and damage to pavement or other road infrastructure. These impacts impose costs on occupants of other vehicles and on the society at large. The numbers of existing and new mode-shift walking trips are obtained from the H-GAC's Bike-Ped Commuter Analysis[15].

No-Build Scenario

The current condition of the existing facilities is not conducive for pedestrians or cyclists.

Build Scenario

The Project will install new sidewalks and rehabilitate existing sidewalks to meet the COH's current design standards, as well as install new bicycle facilities along the project corridor. These amenities will result in modal shift with a reduction in overall VMT.

Methodology/Summary

The 2023 USDOT BCA Guide provides recommended monetized values for external highway use costs. The recommended costs per vehicle mile traveled including all kinds of vehicles in urban locations are $0.144 for congestion and $0.0048 for noise. Equation 10 is used to determine the benefit of reducing congestion externalities.

Equation 10. Congestion Externalities Reduction

Congestion Externalities Reduction = VMT * ($0.144+$0.0048)
VMT = Vehicle Miles Traveled Reduced because of Modal Diversion

The accumulated benefits of increased walking and transit trips on reducing external highway use costs for the analysis period are quantified and discounted at a 7% rate, presented in Table 32.

Table 32. Congestion Externalities Reduction

Scenario	Monetized Value
No-Build Benefit	$72,000

[15] Source: H-GAC Regional Data Hub (2023). Activity-Connectivity Explorer. Retrieved from https://datalab.h-gac.com/ace/

Build Benefit	$317,000
Net Benefit	**$245,000**
Net Benefit Discounted @ 7% to $2021	**$93,000**

Benefits 12 and 13: Emission Reduction Benefits

The EPA has classified the Houston-Galveston-Brazoria area in marginal nonattainment of the eight-hour ozone standard; air quality does not meet federal standards.[16] The investment in mobility infrastructure could produce environmental benefits due to decreased automobile use or vehicle delay which reduces air pollutants and is important to the region's future growth. The numbers of existing and new mode-shift walking trips are obtained from the H-GAC's Bike-Ped Commuter Analysis[17].

No-Build Scenario

The current condition of the existing facilities is not conducive for pedestrians or cyclists.

Build Scenario

The Project will install new sidewalks and bicycle facilities that can accommodate both pedestrians and bicyclists.. These amenities will result in modal shift with a reduction in overall VMT.

Methodology/Summary

H-GAC models NOx using the following emissions factor:

- Nitrogen Oxides (NO_X): 0.19 grams (g) per VMT

United Environmental Protection Agency (EPA) uses the following emissions factor for CO_2:[18]

- Carbon Dioxide (CO_2): 0.0089 metric tons per gallon of gasoline used

NOx and CO_2 have measurable societal economic impacts on the economy. The 2023 USDOT BCA Guide provides recommended monetized values of damage costs for NOx and CO_2 emissions per metric ton by year between 2022 and 2050. These values are

16 United States Environmental Protection Agency (2022). 8-Hour Ozone (2015) Nonattainment Area State/Area/County Report. Green Book. Retrieved September 2022 from https://www3.epa.gov/airquality/greenbook/jncs.html#TX

17 Source: H-GAC Regional Data Hub (2023). Activity-Connectivity Explorer. Retrieved from https://datalab.h-gac.com/ace/

18 Environmental Protection Agency. (n.d.). EPA. Retrieved August 23, 2022, from https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

used to calculate the Project's benefit derived from the reduction of harmful air pollutants.

For active transportation and transit improvements that improve the walkability and bikeability of an area and increase transit utilization, there is a presumed environmental benefit from automobile trips being converted into walking, biking, and transit trips. The VMT benefit is derived and converted into the amount of NOx and CO_2 grams reduced based on the H-GAC emissions factor. VMT is assumed to grow annually at the same rate as internal trips. Accumulated benefits for pedestrian and transit users are quantified over the 20-year analysis period and discounted at a 7% rate, shown in tables below.

Table 33. Emission Reduction Benefits - Walking

Scenario	Monetized Value
No-Build Benefit	$11,000
Build Benefit	$13,000
Net Benefit	**$3,000**
Net Benefit Discounted @ 7% to $2021	**$2,000**

Table 34. Emission Reduction Benefits - Cycling

Scenario	Monetized Value
No-Build Benefit	$0
Build Benefit	$34,000
Net Benefit	**$34,000**
Net Benefit Discounted @ 7% to $2021	**$21,000**