Navigation Boulevard Reconstruction Project

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 Navigation Boulevard Reconstruction Project ("Project") limits are described in Table 1.

Table 1. Project Limits

Street	Terminus A	Terminus B
Navigation Boulevard	Lockwood Drive	Mack 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:

- Close the existing median opening at N. Bryan Street and N Edgewood Street.
- Upgrade all sidewalks along the Navigation Boulevard to at least six feet wide and install ADA-compliant curb ramps at all pedestrian crossings.
- Install 12-foot shared use path (SUP) from N. Stitles Street to Mcfarland Street, and 10-foot SUP from Mcfarland Street to Mack Street
- Raise the SUP in the median to improve safety at median openings to help slow down vehicles and increase visibility of trail users.
- Install high contrast pavement markings, and colored concrete to enhance visibility.
- Install new signalized intersection at McFarland Street.
- Install a rectangular rapid flash beacon at the intersection with Northwood Street.

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

- Prohibit parking except in designated locations at Turkey Bend.
- Remove a travel lane throughout project limits.

Summarized Planning, Design, Environmental, and Capital Costs

The costs (excluding ongoing maintenance) for the Project in the year of expenditure, or nominal dollars, is $11,677,000. 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 values found in Table A-7 in the 2023 USDOT BCA Guide.[1] The total project cost in 2021 real dollars is $10,377,000. These costs are discounted 7% from the expenditure year to year 2021. The total year 2021 real discounted costs are $7,460,000. Project costs are described in Table 2.

Table 2. Project Costs

Cost	Nominal $ Year of Expenditure No Discount	Real $ $2021 No Discount	7% Discount $2021
Design/Environmental	$871,000	$800,000	$632,000
Construction	$10,806,000	$9,577,000	$6,828,000
Project Costs	**$11,677,000**	**$10,377,000**	**$7,460,000**

Summarized Benefits

The proposed Project will provide a variety of societal benefits to the local and regional transportation system.

The No-Build Scenario will result in the following:

- Travel along the Project corridor will remain mostly unimpeded. The only traffic signal is at Lockwood Drive, another Principal Thoroughfare with two travel lanes in each direction. For all other streets, there is no stop control on Navigation Boulevard, while there are stop signs at cross-streets and major driveways.
- The Project corridor will remain unsafe for pedestrians and cyclists. There are few marked crossings for people walking and bicycling. Only two marked crosswalks were observed on visual inspection, neither of which has ADA standard pedestrian ramps or median refuges.
- The Project corridor will continue to lack access control. On both the north and south sides of the street, there are approximately 30 driveways each that provide access to businesses. Within the study area, the median has approximately twelve openings that provide vehicle access to cross streets and allow U-turns.

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: 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 3: Pedestrian Safety Improvements**
  - The Project will experience significant pedestrian safety improvements and as a result, a likely reduction of pedestrian related injuries.
- **Benefit 4: Bicycle Safety Improvements**
  - The Project will experience significant bicycle safety improvements and as a result, a likely reduction of bicycle related injuries.
- **Benefit 5: Facility Improvements – Walking**
  - The Project will improve sidewalks and therefore improve the quality or comfort of journeys made by pedestrians.
- **Benefit 6: Facility Improvements – Cycling**
  - The Project will install new bicycle facilities and therefore improve the quality or comfort of journeys made by cyclists.
- **Benefit 7: Value of Travel Time**
  - The Project will improve the roadway infrastructure, therefore reduce travel delays.
- **Benefit 8: Mortality Reduction Benefits — Walking**
  - The Project will encourage more walking which can lead to a reduction in mortality risks for pedestrians.
- **Benefit 9: Mortality Reduction Benefits — Cycling**
  - The Project will encourage more cycling which can lead to a reduction in mortality risks for bicyclists.
- **Benefit 10: 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 11: 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 12: 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.

The benefit-cost ratio is 9.6 in 2021 real dollars and when discounted at a 7% discount rate, the benefit-cost ratio is 4.5. The 2021 real dollar NPV is $88,889,000 and when discounted at 7%, $25,917,000.

Table 3. BCA Summary

Scenario	$2021 Real Dollars	$2021 Real Dollars 7% Discount
Benefits	$99,266,000	$33,377,000
Costs	$10,377,000	$7,460,000
BCA	9.6	4.5
NPV	$88,889,000	$25,917,000

Table 4 summarizes the Project benefits.

Table 4. Project Benefits Summary

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

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	**$5,746,000**	**$1,059,000**
Benefits 2, 3, and 4: Safety Benefits	Outdated design, disproportionally higher crash rates	Safety improvement resulting in reduction in traffic crashes	Reduced crashes resulting in reduced fatalities and injuries	$3,749,000	$1,724,000
Benefits 5 and 6: 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	$560,000	$212,000
Benefit 7: Value of Travel Time	The current facilities lead to significant delay of users	Improvements to the current facilities will reduce delay	Travel time savings	$84,531,000	$28,611,000
Benefits 8 and 9: 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	$4,557,000	$1,722,000
Benefit 10: Congestion Externalities Reduction	Roadway is not conducive for active transportation	New and improved facilities will encourage more walking and cycling	Reduced congestion externalities	$108,000	$41,000
Benefits 11 and 12: 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	$16,000	$10,000
			Totals	**$99,266,000**	**$33,377,000**

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 $11,677,000. 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 $10,377,000. These costs are discounted 7% from the expenditure year to year 2021. The total year 2021 real discounted costs are $7,460,000.

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	$5,746,000
Net Benefit	**$5,746,000**
Net Benefit Discounted @ 7% to $2021	**$1,059,000**

Benefits 2, 3 and 4: 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.

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

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.[4] 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 6. 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 6. 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

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.

4 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

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 1.

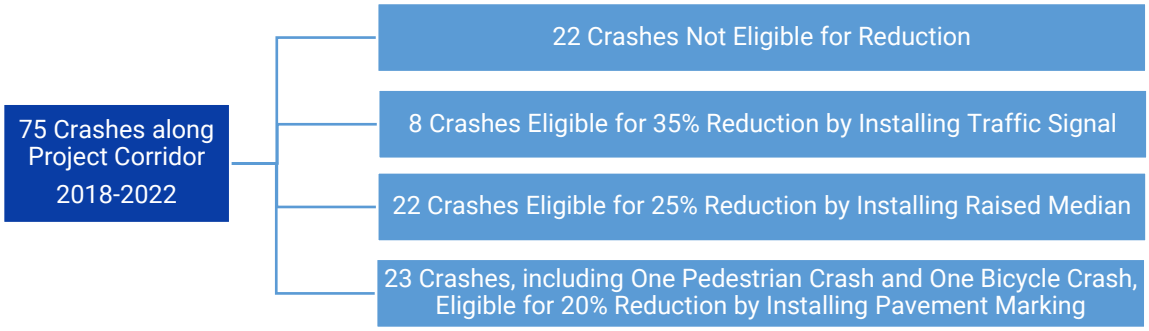

Figure 1. Traffic Crashes and HSIP Work Codes

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

Table 7. Crash Reduction Factor – Install Traffic Signal

Work Code 107: Install Traffic Signal	
Definition	Provide a traffic signal where none existed previously. This does not include the installation of flashing beacons.
Reduction Factor	35%
Service Life (Years)	10
Maintenance Cost	$3,400 (Isolated) $3,900 (Interconnected) $5,400 (Diamond Interchange)
Preventable Crashes	[(Intersection Related = 1 or 2) AND (Vehicle Movements/Manner of Collision =10-39)] OR (First Harmful Event = 1 or 5)

Table 8. Crash Reduction Factor – Install Raised Median

Work Code 203: Install Raised Median	
Definition	Install a roadway divider using barrier curb.
Reduction Factor	25%
Service Life (Years)	20
Maintenance Cost	N/A
Preventable Crashes	(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 9. Crash Reduction Factor – Install Pavement Markings

Work Code 401: Install Pavement Markings	
Definition	Place complete pavement markings, excluding crosswalks, in accordance with the TMUTCD where either no markings or nonstandard markings exist. This work code includes items such as turn arrows, stop bars, lane markings, etc.
Reduction Factor	20%
Service Life (Years)	4 (Product used must meet 4-year service life.)
Maintenance Cost	N/A
Preventable Crashes	(Roadway Related = 1) OR (Vehicle Movements/Manner of Collision = 21 or 30)

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 6. Accumulated benefits for the specified service life are quantified up and discounted at a 7% rate, shown in the following tables.

Table 10. Motorist Safety Benefits

Scenario	Monetized Value
No-Build Cost	$14,062,000
Build Cost	$10,501,000
Net Benefit	**$3,561,000**
Net Benefit Discounted @ 7% to $2021	**$1,607,000**

Table 11. Pedestrian Safety Benefits

Scenario	Monetized Value
No-Build Cost	$158,000
Build Cost	$126,000
Net Benefit	**$32,000**
Net Benefit Discounted @ 7% to $2021	**$20,000**

Table 12. Bicycle Safety Benefits

Scenario	Monetized Value
No-Build Cost	$778,000
Build Cost	$623,000
Net Benefit	**$156,000**
Net Benefit Discounted @ 7% to $2021	**$97,000**

Benefits 5 and 6: 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[5].

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.

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 2.

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

Equation 2. 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 25-year horizon are quantified and discounted at a 7% rate, presented in Table 13.

Table 13. Pedestrian Facility Improvement Benefit

Scenario	Monetized Value
No-Build Cost	$0
Build Cost	$73,000
Net Benefit	**$73,000**
Net Benefit Discounted @ 7% to $2021	**$28,000**

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 14. The Project will install a 6-foot bike lane on the eastbound of Navigation Boulevard from Lockwood Drive to N. Stitles Street and SUP in the median for the rest of the Project corridor. The value of Cycling Path with At-Grade Crossings is used for calculating the improvement benefit.

Table 14. 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 3. 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 3. 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 25-year horizon are quantified and discounted at a 7% rate, presented in the following table.

Table 15. Cycling Facility Improvement Benefit

Scenario	Monetized Value
No-Build Benefit	$0
Build Benefit	$487,000
Net Benefit	**$487,000**
Net Benefit Discounted @ 7% to $2021	**$184,000**

Benefit 7: 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 traffic flow and reduce travel times for drivers.

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 projecting 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 decrease average vehicle delays at the intersections along the Project corridor. Therefore, the Project will benefit travel time savings of motor vehicles.

The traffic impact analysis provides the average delay reduced 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). Using Equation 4, the users' value of time for the Project is calculated.

Equation 4. 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 for the 25-year horizon are quantified and discounted at a 7% rate, presented in Table 16.

Table 16. Summary Value of Travel Time Costs

Scenario	Monetized Value
No-Build Cost	$149,160,000
Build Cost	$64,628,000
Net Benefit	**$84,531,000**
Net Benefit Discounted @ 7% to $2021	**$28,611,000**

Benefits 8 and 9: 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[6].

No-Build Scenario

The existing sidewalks do not meet the requirement of the City of Houston and there is a lack of bicycle facilities.

Build Scenario

The Project will install new sidewalks, bike lanes, and shares use paths.

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

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 5 is used to estimate the mortality reduction benefits of induced walking trips.

Equation 5. Mortality Reduction Benefits - Walking

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

The accumulated benefits of mortality reduction benefits for the analysis period are quantified and discounted at a 7% rate, presented in Table 17.

Table 17. Mortality Reduction Benefit - Walking

Scenario	Monetized Value
No-Build Cost	$0
Build Cost	$1,018,000
Net Benefit	**$1,018,000**
Net Benefit Discounted @ 7% to $2021	**$385,000**

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 6 is used to estimate the mortality reduction benefits of induced cycling trips.

Equation 6. 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 18.

Table 18. Mortality Reduction Benefit - Cycling

Scenario	Monetized Value
No-Build Cost	$0
Build Cost	$3,539,000
Net Benefit	**$3,539,000**
Net Benefit Discounted @ 7% to $2021	**$1,337,000**

Benefit 10: 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.

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. The

number of mode-shift walking and biking trips are obtained from the H-GAC's Bike-Ped Commuter Analysis[7]. Equation 7 is used to determine the benefit of reducing congestion externalities.

Equation 7. 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 19.

Table 19. Congestion Externalities Reduction

Scenario	Monetized Value
No-Build Benefit	$20,000
Build Benefit	$128,000
Net Benefit	**$108,000**
Net Benefit Discounted @ 7% to $2021	**$41,000**

Benefits 11 and 12: 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.[8] 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 number of mode-shift walking and biking trips are obtained from the H-GAC's Bike-Ped Commuter Analysis[9].

No-Build Scenario

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

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

8 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

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

Build Scenario

The Project will install new shared use paths that can accommodate both pedestrians and bicyclists that 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:[10]

- 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 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 20. Emission Reduction Benefits - Walking

Scenario	Monetized Value
No-Build Benefit	$2,000
Build Benefit	$5,000
Net Benefit	**$3,000**
Net Benefit Discounted @ 7% to $2021	**$2,000**

Table 21. Emission Reduction Benefits - Cycling

Scenario	Monetized Value
No-Build Benefit	$1,000

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

Build Benefit	$14,000
Net Benefit	**$13,000**
Net Benefit Discounted @ 7% to $2021	**$8,000**