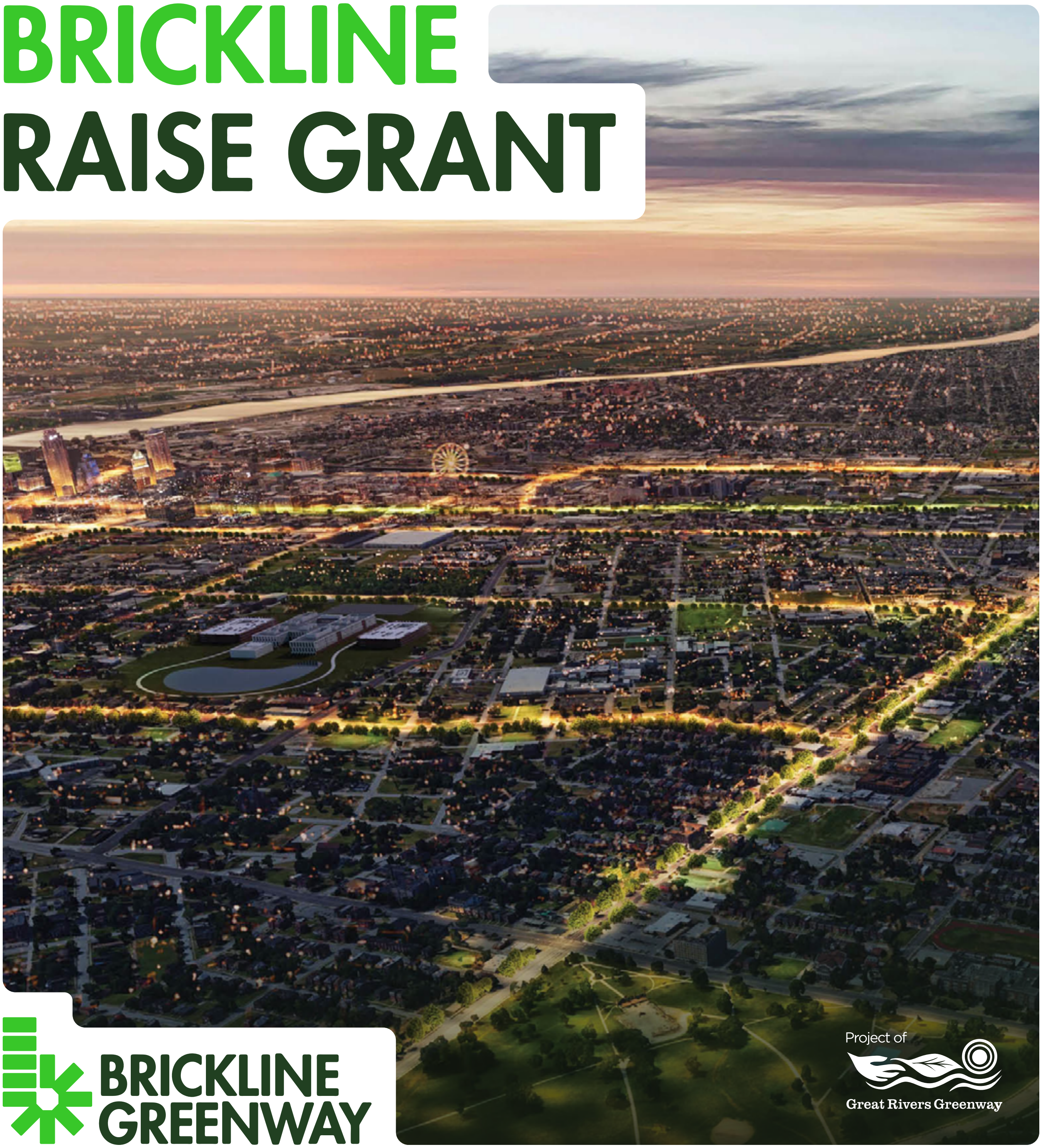
BENEFITS COST ANALYSIS SUPPORTING DOCUMENTATION

BRICKLINE RAISE GRANT



BRICKLINE GREENWAY

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EXECUTIVE SUMMARY

The future Brickline Greenway is a 20-mile network of greenways that will connect vibrant neighborhoods of St. Louis and create meaningful experiences for the people who live there. The proposed Brickline Greenway: Fairground Park to City Foundry Connector project, and subject of this benefit-cost analysis, is a vital 2.2-mile segment of the Brickline Greenway that extends from Fairground Park in the Fairground neighborhood to Forest Park Ave in Midtown near the campus of St. Louis University. The proposed project includes a physically separated sidepath, lane reconfigurations, and bicycle and pedestrian friendly design elements.

The Brickline is the result of extensive public engagement efforts and reflects the community's desires to improve civic well-being; connect neighborhoods, jobs, and public spaces; create opportunities for equitable economic growth; be a model for environmental stewardship; and encourage active transportation to improve physical and mental well-being.

The RAISE Grant provides the applicant, Great Rivers Greenway (GRG), an opportunity to leverage local funds and bring immediate benefits to communities of North St. Louis. **Table 1** illustrates project benefits and the corresponding RAISE Grant merit criteria. There are numerous anticipated benefits from this project detailed in this document; however, not all benefits are quantified and monetized. The benefit cost analysis provides a data driven approach to measure the benefits of the proposed project. This analysis follows guidance from the USDOT BCA Guidance document.

Table 1: Summary of Project Benefits

RAISE Grant Primary Merit Criteria	Benefits	Quantified	Part of BCA
Safety	Reduces crashes along project corridor	Yes	Yes
	Improves community cohesion	--	--
Environmental Sustainability	Addresses environmental justice communities	--	--
	Addresses climate change	Yes	Yes
	Improves water quality	--	--
	Increases access to open space	--	--
Quality of Life	Reduces mortality and improves health outcomes	Yes	Yes
	Increases transportation choices and equity	--	--
	Addresses racial equity	--	--
	Improves civic participation	--	--
Economic Competitiveness	Improves travel times along the corridor	Yes	Yes
	Increases economic development	Yes	--
State of Good Repair	Reduced operating and maintenance costs	Yes	Yes

Table 2 illustrates total project costs and project benefits. The proposed project is expected to generate $154,984,442 in total benefits (net present value) and has a benefit-cost ratio of **4.61.**

Table 2: Benefit-Cost Analysis Summary

Benefit/Cost	Non-Discounted	Discounted at 7% Annually
Benefits		
Safety Benefits	$271,509,672	$105,599,674
Emission Reduction Benefits	$40,240	$21,794
Travel Time Benefits	$10,479,498	$4,078,007
Reduced Health and Mortality Benefits	$12,690,707	$5,033,150
State of Good Repair Benefits	$2,166,757	$852,944
Summary		
Net-Present-Value (NVP) of Benefits	$388,170,107	$154,984,442
Net-Present-Value (NVP) of Costs	$50,436,076	$33,625,773
Benefits-Costs-Ratio (BCR)	***4.61***	

INTRODUCTION

This report details the technical aspects of the benefit-cost analysis (BCA) conducted as part of the Brickline Greenway: Fairground Park to City Foundry Connector RAISE Grant application. The information is discussed in the following 8 sections:

1 **Framework**
Introduces the methodological framework of the analysis. The method was developed using guidance from USDOT and is consistent with RAISE grant program guidelines.

2 **General Assumptions**
Describes the general assumptions to estimate project costs and benefits. More specific assumptions pertaining to detailed calculations are outlined in the individual benefit sections.

3 **Project Overview**
Provides the context and scope of the proposed project. The scope aligns with the impacts and benefits identified and evaluated in this analysis. Total project costs and the project schedule are also discussed in this section.

4 **Demand Projections**
This section describes the projections made to quantify the anticipated users of the proposed project. More specifically, projections are based on the number of users the project expects to divert from adjacent roadways and were determined via modal diversion estimation. Two modal diversion estimates were used: diversion to bicycling or walking and diversion to transit.

5 **Project Benefits**
Project benefits are described in five categories: Safety, Emissions, Travel Time, Quality of Life, and State of Good Repair. Context, assumptions, method, and monetary benefits are outlined in detail for each benefit category.

6 **Summary of Findings**
Summarizes the findings and outcomes of the BCA. Monetary benefits and total costs are summarized and aggregated. BCA outcomes such as net present value and benefit-cost ratio are presented.

7 **Sensitivity Analysis**
Describes the performed sensitivity analysis to ensure the BCA is robust. Due to various factors, the variables within the BCA are subject to uncertainty. The sensitivity analysis illustrates how the results of the BCA would change when various alternatives and parameters incrementally vary.

8 **Unquantified Additional Benefits/Analyses**
Within the USDOT BCA Guidance, there are several other noteworthy benefit categories which are impacted by this project but are not able to be quantified within the BCA for various reasons. This section describes the relevance of these impacts and notes that consideration was brought to these benefit categories.

1 FRAMEWORK

BCA estimates the future benefits of a project or improvement and compares them to the total costs of project or improvement. The BCA conducted for this project identifies and quantifies expected benefits, monetizes the benefits using the USDOT Benefit Cost Analysis Guidance 2021 where applicable, or other authoritative source information if necessary, and compares the benefits to the capital and maintenance costs over the expected life of the project.

The method utilized for this analysis was developed using the USDOT BCA Guidance and is consistent with RAISE Grant program guidelines. This method includes the following steps:

- Establish conditions under Build and No-Build scenarios
- Identify and assess project benefits as detailed in the merit criteria in the Notice of Funding Opportunity (NOFO)
- Measure benefits in dollar terms (using USDOT BCA guidance when possible and industry best practices or other authoritative sources) for each of the five benefit categories: safety, emissions, travel time, health and reduced mortality, and state of good repair
- Establish capital and operating and maintenance costs estimates
- Discount future costs and benefits with discount rates recommended by USDOT
- Compare project costs and benefits in common unit of measurement; Net Present Value (NPV), Benefit-Cost Ratio (BCR)
- Conduct sensitivity analysis on critical variables in the model to ensure a robust analysis (Monte Carlo Simulation)

2 GENERAL ASSUMPTIONS

BCA provides estimates of the anticipated project benefits compared to the expected costs over a period of time. Typically, costs include the resources required to develop and maintain the project throughout its lifespan. On the other hand, benefits may be accrued from impacts on both users and non-users of the facility or project.

The monetized benefits are estimated in 2021 US dollars. The BCA method relies on several important assumptions regarding both the existing facility and project under study, specifically:

- The period of analysis beginning in 2021 and ending in 2046. This timeframe includes project construction, beginning in 2024 with expected completion in 2026, with twenty operational years.
- First year anticipated benefits are expected in 2026.
- All future discounted dollars are discounted at the seven percent annual rate per USDOT RAISE Grant Guidance.

3 PROJECT OVERVIEW

3.1 Context

St. Louis City can be broken down into north, south, east, and west boroughs of the city. Over many years, these boroughs have become divided by real and perceived barriers. By developing a network of greenways, connections would be developed between the city's vibrant neighborhoods, parks, business and arts districts, employment centers, transit hubs, and myriad cultural and educational institutions while promoting equity, economic development, and connectivity.

In order to bridge the divide, the Brickline Greenway, formerly referred to as Chouteau Greenway, was developed not only to connect Forest Park in the west to the Gateway Arch to the east, but also connects Fairground Park to the north to Tower Grove Park in the south. In total, the greenways would span up to 20 miles connecting approximately 17 neighborhoods and all the destinations in between. The full Brickline Greenway network is depicted in **Figure 1**.

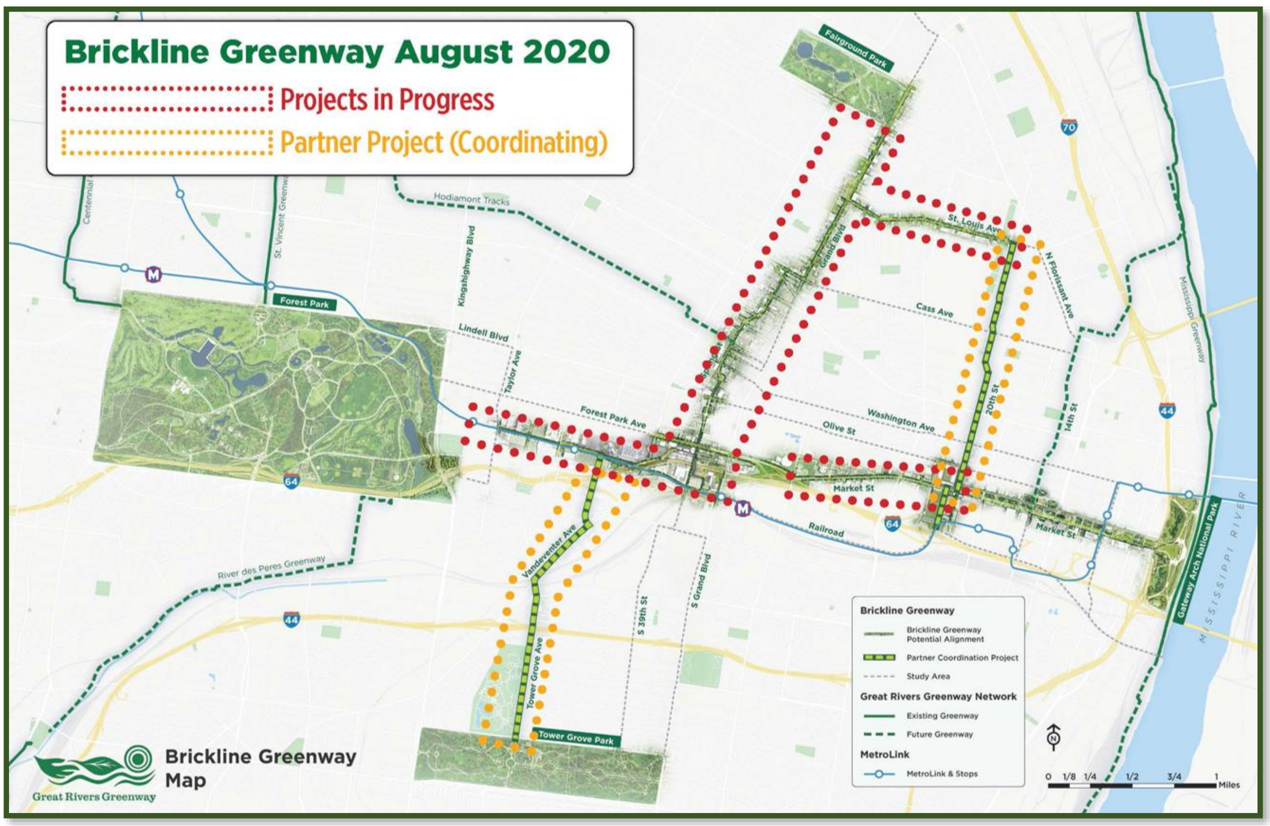

Figure 1. Overall Brickline Greenway Area Map

3.2 Description

The Brickline Greenway: Fairground Park to City Foundry Connector, which is the subject of this grant application, includes the 2.2-mile section of greenway extending from Fairground Park to Forest Park Ave near the campus of St. Louis University. The subject section is shown in **Figure 2**.

The project area currently lacks a network of protected bicycle facilities. Many sidewalks are in disrepair, are of insufficient width, lack ADA compliance, and feature minimal pedestrian markings and signalization at intersections. Pedestrian and bicycle crossings of N Grand Blvd in the project area are hazardous due to fast-moving traffic along Grand. This project offers the opportunity to further the broad multi-modal and active transportation strategy articulated through previous planning efforts by providing more robust pedestrian and bicycle infrastructure.

Figure 2. Project Alignment

The greenway will be a physically separated sidepath, constructed within the existing right-of-way and will include amenities such as directional signage, bicycle parking, bike repair stations, and art installations. Other bicycle pedestrian amenities include ADA compliant crossings at intersections, new mid-block crossings, 12-foot sidewalks, and a new brick paver median. In addition to the construction of the greenway, the project includes lane reconfigurations along the project corridors. Cross sections on N Grand Blvd and Cass Ave will be reconfigured from four lanes to three lanes (one lane in each direction plus a two-way left turn lane). The cross section on Spring Ave will be reconfigured from four lanes to two lanes. Lane reconfigurations will be combined with new traffic signalization, fiber interconnect, and optimized signal timings. Landscaping components are an important part of the greenway design. The proposed project includes approximately 823 trees planted in Silva Cell tree and stormwater management systems.

3.3 No-Build versus Build Scenarios

In order to complete the analysis, a clear baseline (No-Build) was established. The No-Build scenario describes the variables in the analysis in the absence of the proposed project. The No-Build conditions were forecasted over the analysis period. The alternative (Build) scenario describes the conditions as a result of the proposed project as described in the previous section. The No-Build and Build scenarios are compared to determine the full extent of project benefits.

3.4 Types of Impacts

Project impacts were identified to establish potential benefits or disbenefits. Within each category, anticipated project impacts are described relative to the assumptions, method, and quantified benefits. The descriptions of each benefit category are as follows:

1. <u>Safety:</u> The proposed project will reduce the number and severity of vehicle crashes along the corridor.
2. <u>Emissions:</u> The proposed project will divert motor vehicles to other modes such as pedestrian or bicycle and reduce vehicle stop/starts. Reduced motor vehicle use will reduce emissions.
3. <u>Travel Time:</u> The proposed project will optimize signal timing along the corridor. The signal timing optimization will improve travel times.
4. <u>Health and Reduced Mortality:</u> The proposed project will divert motor vehicles to other modes such as pedestrian or bicycle. Active forms of transportation such as walking, or bicycling will reduce annual fatalities by improving health.
5. <u>State of Good Repair:</u> The proposed project will reduce annual wear and tear of the roadway and reduce total lane miles to be maintained. Reduced maintenance needs will provide cost savings.

3.5 Project Cost and Schedule

The total capital costs are projected to be $39,148,576. The anticipated project schedule estimates construction beginning in 2024 and completing in 2026. From 2026 – 2046, annual operating and maintenance costs are projected to be $250,000 (non-discounted) per year, per mile. Total Net Present Value (NPV) of costs, discounted, is $33,625,773.

4 DEMAND PROJECTIONS

Many of the anticipated benefits within this analysis are related to the expected demand or usage of the project improvements and is strictly based on the number of users the project expects to divert from adjacent roadways. The expected users were determined via modal diversion estimation. Modal diversion attempts to estimate the number of users who currently use a specific means of transportation and will be diverted to a different means once the project is completed. The method used to estimate modal diversion follows those outlined in the *Methodology for Assessing the Benefits of Active Transportation Projects*, published for The Trust for Public land's climate – Smart Cities program.[1]

[1] Rose, E., & Choe, J. (2015). Climate Smart Cities - Methodology for assessing the benefits of active transportation projects (Rep.).

Two separate calculations are performed in order to estimate the modal diversion as a result from the project:

1. Reduced vehicle trips due to bicycling and walking; and
2. Reduced vehicle trips due to transit.

It should be noted that this method has been utilized for three successful Congestion Mitigation and Air Quality (CMAQ) grant applications for federal funding distributed by East-West Gateway, which is the region's Metropolitan Planning Organization, and therefore deemed a reliable means to estimate model diversion.

4.1 Adjacent Corridor Traffic

In order to quantify Annual Average Daily Traffic (AADT), vehicle traffic data was obtained from the Missouri Department of Transportation (MoDOT) traffic database. The database provides historical AADT projections for roadways within Missouri state lines. Two segments were of focus: (1) N Grand Blvd between Natural Bridge Ave to Cass Ave, and (2) N Spring Ave between Cass Ave and Lindell Blvd.

Traffic growth within the area was informed by East-West Gateway's travel demand model and assumed to grow at an annual rate of 0.5 percent.

4.2 Reduced Vehicle Trips Due to Bicycling and Walking

This method quantifies the users who previously utilized a vehicle as means of transportation and are diverted to either bicycling or walking as a result of the project improvements. Additionally, the method adjusts for activity centers along the corridor under focus.

The number of diverted users due to bicycling and walking can be estimated from **Equation 1**. This equation was applied separately for the N Grand Blvd segment between Natural Bridge Blvd and Cass Ave and for the N Spring Ave segment between Cass Ave and Lindell Blvd.

Equation 1

$$VT_{B,P} = (BIKE * D * AADT * [A + C\ ]) + (PED * D * AADT * [A + C])$$

$$where:$$

$$VT_{B,P} = Annual\ vehicle\ trips\ reduce\ dto\ bicycling\ and\ walking$$

$$BIKE = Binary\ variable\ indicating\ whether\ the\ project\ has\ a\ bicycle\ component$$

$$PED = Binary\ variable\ indicating\ whether\ the\ project\ has\ a\ pedestrian\ component$$

$$D = Number\ of\ days\ per\ year\ that\ people\ use\ the\ facility$$

$$AADT = Annual\ average\ daily\ traffic\ on\ a\ parallel\ roadway$$

$$A = Adjustment\ factor\ (based\ on\ AADT, facility\ length, and\ where\ the\ project\ is\ located\ in\ surrounding\ univerity\ area$$

$$C = Activity\ center\ credit\ (based\ on\ the\ number\ of\ activity\ centers\ located\ within\ a\ quarter\ or\ half\ mile\ of\ the\ project$$

4.3 Reduced Vehicle Trips Due to Transit

This section of N Grand Blvd is one of the most heavily patronized routes in Bi-State's Metrobus system, with over 400 boardings and 400 alightings on an average day according to 2018 data. Bi-State

Development is currently planning a project to upgrade the buses along the corridor to electric buses along with charging stations along the route.

Given the high ridership along the Grand Blvd corridor, current vehicle trips may be reduced due motorists choosing to access metrobus boarding stations along N Grand Blvd due to the new greenway connections. The reduction in vehicle trips due to new trail connections to transit boarding stations can be estimated by **Equation 2**.

Equation 2

$$VT_T = TRANS * D * B * T$$
$$where:$$
$$VT_T = AAnnual\ auto\ trips\ reduced\ to\ new\ transit\ trips$$
$$TRANS = Binary\ variable\ indicating\ whether\ the\ project\ provides\ direct\ access\ to\ transit$$
$$D = Number\ of\ days\ per\ year\ that\ people\ use\ the\ facility$$
$$B = Daily\ transit\ boarding\ at\ the\ stations\ served\ by\ the\ project$$
$$T = Increase\ in\ transit\ trips\ (based\ on\ the\ area\ and\ transit\ type)$$

4.4 Mode Choice

To determine health and reduced mortality benefits, the total number of diverted motorists must be distributed between walking or bicycling. For mode choice selection, the Missouri Census Data Center (MCDC) was referenced for demographic data within St. Louis City. MCDC's "Commuting to Work" section was utilized to determine the breakdown for means of transportation within the study area. More specifically, this data was utilized to determine the percent of new users which would be either walking or biking. The MCDC data for mode choice in St. Louis City is summarized in **Table 3**.

Table 3. MCDC Commuting to Work Data (St. Louis City)

Mode	Percent of Usership
Car	81%
Public Transportation	9%
Walk	5%
Other means	2%
Stayed Home	4%

Of the 2% of users who used "Other Means" of commuting to work, half (1%) were assumed to bicycle, and half would remain "Other". This brings walking to 5% and bicycling to 1% for a total of 6% mode share. Of the total number of motorists diverted from Sections 4.2 and 4.3, 84% (5/6^{ths}) and 16% (1/6th) are assumed to be new pedestrians and bicyclists, respectively.

5 PROJECT BENEFITS

5.1 Safety

Safety benefits are generated by implementing countermeasures within the study area. Vehicle crash data was obtained from MoDOT's historical crash database. Data was obtained over a five-year horizon, beginning in 2015 and ending in 2019. Crash data was obtained throughout the study area consisting of any crashes occurring along the N Grand Blvd or N Spring Ave corridors. Similarly, any crashes along the side-streets which were determined by the state of Missouri to occur within an intersection in study limits were also included. In total, 563 and 170 crashes occurred along the N Grand Blvd and N Spring Ave corridors, respectively, between 2015 and 2019.

In January of 2021, a research study published in the *Journal of Transport and Land Use* identified the N Grand Blvd corridor between Greer Ave and Cote Brilliante Ave as one of the highest fatal pedestrian crash hot spot corridors within the United States[2], the entirety of which is encompassed in the subject area. Hence, the N Grand Blvd corridor is in dire need of the correctable safety countermeasures to be provided by the current project.

5.1.1 Assumptions

MoDOT's crash severity scale does not directly follow KABCO classification schema, but the two scales have very similar severity classes. For this analysis, the MoDOT crash severities were assumed to align with the KABCO scale in the fashion depicted in **Table 4**.

Table 4. Crash Severity Classification Assumptions

KABCO Classification	MODOT Classification
K - Killed	Fatal
A - Incapacitating	Disabling Injury
B - Non-incapacitating	Minor Injury
C - Possible Injury	Suspected Serious Injury
O - No Injury	Property Damage Only
U - Injured (severity unknown)	-

It is assumed that traffic growth is directly correlated to the number of crashes occurring along the corridors. Therefore, the annual traffic growth rate of 0.5 percent was applied to forecast crashes in future years. This rate was informed by the travel demand model maintained by East-West Gateway, the St. Louis region's Metropolitan Planning Organization.

In order to estimate safety benefits, the USDOT BCA Guidance was referenced for the following factors and or assumptions:

- 1.44 injuries per injury crash
- 1.09 fatalities per fatality crash

[2] Schneider, R. J., Sanders, R., Proulx, F., & Moayyed, H. (2021). United States fatal pedestrian crash hot spot locations and characteristics. Journal of Transport and Land Use, 14(1), 1-23.

Similarly, the monetarization values for each crash type, provided by the USDOT BCA Guidance, is summarized in **Table 5**.

Table 5. USDOT BCA Guidance Monetized Values by Crash Severity

KABCO Level	Monetized Value Per Event
O – No Injury	$3,700
C – Possible Injury	$72,500
B – Non-incapacitating	$142,000
A – Incapacitating	$521,300
K – Killed	$10,900,000
U – Injured (Severity Unknown)	$197,600
# Accidents Reported (Unknown if Injured)	$150,200

5.1.2 Method

During field observations performed by a traffic engineering consultant on May 19, 2021, vehicle speeds and traffic signal compliance were notable issues along the N Grand Blvd corridor. Inspecting the historical crashes along the N Grand Blvd corridor not only yields an alarming number of crashes, but significant number of crashes resulting in injuries and fatalities.

N Grand Blvd is classified as a principal arterial traveling in the north-south directions with a posted speed limit of 35 miles per hour (mph). MoDOT cites AADT values for N Grand Blvd at approximately 13,000 vehicles per day. The current cross section provides two travel lanes in each direction with on street parking provided along certain segments of the corridor. As part of this project, the corridor would be subject to a road diet with upgraded traffic signals and ADA compliant crosswalks at signalized intersections. The road diet would reduce N Grand Blvd and Cass Ave's four-lane cross sections to three lanes (one each direction plus a two-way-left-turn lane).

The narrower cross-sections would be significantly more pedestrian- and bicycle-friendly as the smaller cross-section reduces these more vulnerable modes' exposures to vehicle traffic. Typically, road diets reduce speeds and are a countermeasure against crashes as vehicles can no longer pass each other. Per CMFClearinghouse.com, a 4-to-3 road diet such as that to be implemented along N Grand Blvd and Cass Ave has a Crash Modification Factor (CMF) of 0.53 for all types and severities of crashes. This means that with an implementation of a road diet, it is expected to reduce crashes along the corridor by 47% (1 minus 0.53).

Similarly, it should be noted that four vehicle-pedestrian fatalities occurred along N Grand Blvd, all concentrated at its intersection with Montgomery Street. For this reason, the proposed project plans to implement rectangular rapid flashing beacons (RRFB) at Montgomery Street. This also has a CMF of approximately 0.53.

The applied road diet countermeasure reduces crashes by 47 percent for all severities and crash types along principal arterials. Additionally, the countermeasure for installing an RRFB was applied to the four vehicle-pedestrian fatalities occurring at Montgomery Street. The applied countermeasures are summarized in **Table 6**.

Table 6. Applied Safety Countermeasures

Countermeasure	CMF	CMF ID	Crash Severity	Crash Type
Implement Road diet (4 to 3)	0.53	2841	ALL	ALL
Install RRFB	0.526	9024	ALL	Vehicle-Pedestrian

Note, the road diet is only applied to the N Grand Blvd corridor. The proposed cross section of N Spring Ave will reduce the number of travel lanes from four to two. The reduced cross-section will be a benefit as it reduces vehicle speeds and more vulnerable users have a shorter distance to cross resulting in less pedestrian exposure to vehicles. However, there is not an available CMF for this 4-to-2 type of road diet; therefore, the benefit of reduced pavement on N Spring Ave as it applies to safety was not calculated or monetized.

The crashes occurring between 2015 and 2019 were averaged over a five-year horizon to determine the average number of annual crashes by severity. As mentioned previously, crashes occurring along N Grand Blvd were forecasted at a 0.5 percent annual growth rate. To estimate the monetary value of implementing a road diet, fatalities per crash and injuries per crash were scaled by the USDOT BCA Guidance values. Lastly, the annual crashes were multiplied by the monetary value for each crash event from Table 5 to determine the total net benefits.

To calculate the impact of the applied road diet and RRFB countermeasures, the forecasted number of crashes were multiplied by CMFs from Table 6. Similarly, the annual crashes were multiplied by the monetary value for each crash event from Table 5 to determine the total net benefits.

5.1.3 Estimated Crash Reduction Benefits

The N Grand Blvd corridor has experienced a significant number of crashes over the years, with an alarming number resulting in injuries and fatalities. Crash reduction benefits generated by implementing a road diet on N Grand Blvd, reducing from four travel lanes down to two plus a two-way left turn lane, and the implementation of a Rectangular Rapid Flashing Beacon at N Grand Blvd and Montgomery Street estimate approximately $145,892,982 (discounted) in total benefits.

5.2 Emissions

The reduction in vehicle miles traveled due to modal diversion is expected to have a benefit as vehicle emissions would be reduced. Persons who previously utilized vehicles along the study corridors would now walk or bike as a result of the project being implemented as calculated previously in Section 4.4.

5.2.1 Assumptions

Emission rates were not available for a St. Louis City EPA MOVES model. For this reason, vehicle emissions rates were referenced from a publication titled *"Sample Calculation of Emission Reductions and Fuel Savings from a Carpool Program"* (publication number: EPA420-F-08-028), published in the EPA's National Service Center for Environmental Publications[3]. The emission rate for sulfur dioxide was referenced from a publication titled *"Characterization of Emission Factors Concerning Gasoline, LPG, and*

[3] Sample Calculation of Emission Reductions and Fuel Savings from a Carpool Program - Emission Facts. (2008). National Service Center for Environmental Publications (NSCEP), EPA420-F-08-028.

Diesel Vehicles via Transient Chassis-Dynamometer Tests" (doi:10.3390/app9081573), within the Applied Sciences journal[4]. The assumed vehicle emission rates are summarized in **Table 7**.

Table 7. Vehicle Emission Rates

Green Has Gate	Emissions Rate	Unit
Nitrogen oxides (NOx)	0.693	grams/mile
Particulate Matter (PM2.5)	0.0041	grams/mile
Carbon Dioxide (CO2)	368.4	grams/mile
Sulfur dioxide (SO2)	0.0004	grams/mile

5.2.2 Method

Utilizing the method applied from Section 4, the number of vehicles diverted to a new means of transportation were multiplied by the segment length of each corridor, resulting in a savings of annual VMT. Total pollution reduction can be directly calculated via the VMT savings and multiplying by the rates shown in Table 7.

USDOT BCA Guidance provides damage costs per metric ton for each greenhouse gas forecasting out to 2050. Emission benefits are found by multiplying the total annual emittance for each pollutant by the corresponding year's damage cost.

5.2.3 Emission Reduction Benefits

Emission reduction benefits are estimated at approximately $21,794 (discounted). All vehicle pollutant savings were discounted at seven percent and carbon dioxide was discounted at three percent, per USDOT BCA Guidance.

5.3 Travel Time

The proposed project would have a significant impact on travel time savings for motorists along the N Grand Blvd corridor. The reduction in vehicles due to modal diversion may be viewed as a benefit as there are less motorists on the road resulting in less congestion and delays. However, implementing a road diet may be viewed as a benefit or disbenefit depending on if the reduced number of travel lanes increases travel times along the corridor.

[4] Park G, Mun S, Hong H, Chung T, Jung S, Kim S, Seo S, Kim J, Lee J, Kim K, Park T, Kang S, Ban J, Yu D-G, Woo J-H, Lee T. Characterization of Emission Factors Concerning Gasoline, LPG, and Diesel Vehicles via Transient Chassis-Dynamometer Tests. Applied Sciences. 2019; 9(8):1573. https://doi.org/10.3390/app9081573

Road diets work quite well on roadways with average daily traffic of less than 15,000 vehicles per day (vpd). Studies have shown that one lane in each direction with a left turn bay can typically accommodate as much traffic as a four-lane road with no left turn bays since the inner lane in each direction acts as a de facto left turn lane, as shown in Figure 3 from the FHWA *Road Diet Informational Guide*. Road diets can also apply to roads with vehicular traffic of up to approximately 20,000 vpd, but a traffic study is suggested to be performed when daily traffic exceeds 15,000 vpd.

Figure 3: Four-lane Undivided Roadway Operating as a de facto Three-lane Cross Section

Traffic signals along the alignment are aged and will be upgraded with the project. The upgrade will include installing fiber interconnect and Intelligent Transportation Systems (ITS) hardware following City of St. Louis standards. The fiber interconnect will connect these signals to the City's Transportation Management Center and the city may run coordinated timing plans as they see fit to improve traffic flow along the corridor. The two intersections along the corridor that are owned and maintained by the Missouri Department of Transportation (MoDOT) will be designed using MoDOT standards.

5.3.1 Assumptions

Per the USDOT BCA Guidance, the following assumptions are summarized in **Table 8**. As stated previously, traffic within the area is assumed to grow 0.5 percent annually. Similarly, 250 commuter days are assumed per year along the corridor[5]. The N Spring Ave corridor does not operate with a coordinated signal system. Given the number of stop-controlled intersections and minor traffic volumes, benefits or disbenefits pertaining to travel time along this half of the study alignment are deemed negligible and travel time benefits were focused on N Grand Blvd.

Table 8. USDOT BCA Guidance Travel Time Assumptions

Variable	Value	Unit
Average Vehicle Occupancy - All Travel	1.67	persons/vehicle
All Purposes	$17.9	USD/hour
Truck Drivers	$30.8	USD/hour

5.3.2 Method

In order to quantify existing traffic volumes within the study area, turning movement counts performed in 2016 associated with the nearby Project Connect development for the National Geospatial Agency currently under construction were referenced at the signalized intersections along the N Grand Blvd corridor. Manual turning movement counts were performed at any signalized intersection where

[5] LochGroup Assumption; assume 50 work weeks per year and 5 work days per week

historical counts were missing. Traffic signal timings were provided by MoDOT and the City of St. Louis for each traffic signal along the corridor.

A traffic model was developed for the N Grand Blvd corridor utilizing Synchro 10 traffic modeling software, which is based upon the methodologies outlined in the Highway Capacity Manual (HCM) 6th Edition, last updated in 2016 by the Transportation Research Board. The performance of a transportation system is quantified by Levels of Service (LOS), which are measures of traffic flow that consider factors such as speed, delay, interruptions, safety, and driver comfort. Similarly, Synchro provides travel time and LOS estimates for coordinated traffic signal systems.

Under no-build conditions, the traffic model reflects the existing lane configurations and signal timings. The traffic model was modified to depict the road diet lane configurations and or cross-section with the proposed project improvements in place.

Similarly, given the traffic signal modifications along the corridor, coordinating timing plans should be developed and implemented to minimize delays and queues experiencing by motorists. Signal timing coordination plans were optimized in the build scenario with the objective of minimizing north-south travel time for motorists along the N Grand Blvd corridor.

Vehicle AADT was scaled by the average vehicle occupancy and then multiplied by the travel time for each scenario to determine annual vehicle hours traveled (VHT). The monetized travel time benefit could then be estimated for passenger cars and trucks based on the US dollar value per time summarized in Table 8. The full detailed traffic analysis is attached as an Appendix to this grant application.

5.3.3 Estimated Travel Time Benefits

Travel time benefits are estimated at approximately $3,881,684 (discounted). Despite the reduction in through lanes due to the road diet, signal timings were optimized in a fashion which generated approximately an eight percent reduction in travel time as compared to no-build conditions.

5.4 Health and Mortality (Quality of Life) Benefits

The proposed project is expected to improve quality of life by reducing mortality risk. Social benefits accumulate from increased physical activity due to new bicyclists and pedestrians who were diverted from other modes of transportation and now benefit from the project improvements.

5.4.1 Assumptions

According to the Federal Highway Administration’s (FHWA) Pedestrian Safety Guide for Transit Agencies, most people are willing to walk up to a half-mile to a nearby transit stop. Given the characteristics of the corridor and the distance between metro bus stops, the assumed average walking distance of a half mile was deemed sufficient[6].

It should be noted that bicyclists are willing to travel much further as compared to a pedestrian. The National Household Travel Survey estimated that the average bicyclist trip is approximately 2.5 miles.

[6] LochGroup Assumption - informed by AASHTO Chapter 4: Actions to Increase the Safety of Pedestrians Accessing Transit

However, given the length of the corridor segments, the average bicyclist trip distance was assumed to be 1.75 miles[7].

Other assumptions were required in order to apply the method in the *Methodology for Assessing the Benefits of Active Transportation Projects*, published for The Trust for Public land's climate – Smart Cities program are all summarized in **Table 9**.

Based on St. Louis climatology, it was assumed that the region has 190 bikeable commuter days in a year[8]. The value of a statistical life was provided via the USDOT BCA Guidance.

Table 9. Quality of Life Assumptions

Variable	Value	Unit
Commuter Days per Year	190	days
Average Walking Trip Distance	0.25	miles
Average Cycling Trip Distance	1.75	miles
Average Walking Speed	3	miles per hour
Average Cycling Speed	8.7	miles per hour
Relative Mortality Risk Bicycling	0.9	-
Relative Mortality Risk Walking	0.89	-
Reference Volume Bicycling	100	min/week
Reference Volume Walking	168	min/week
Mortality Rate	821.5	deaths/100,000 people
Value of a Statistical Life	$10,900,000	USD

5.4.2 Method

The method used to estimate reduced mortality benefits follows that from the *Methodology for Assessing the Benefits of Active Transportation Projects*, published for The Trust for Public Land's climate – Smart Cities program. This system uses the same method developed by the World Health Organization (WHO) for its Health Economic Assessment Tool (HEAT).

First, minutes of physical active travel must be calculated per week and per user using **Equation 3**. Note, this value is calculated for both bicyclists and pedestrians.

Equation 3

$$T_x = VMT_X / \ U_x * W \ / \ S_X * 60$$

$$where:$$

$$T_X = Minutes\ per\ week\ of\ travel\ by\ mode\ x$$

$$VMT_X = Annual\ VMT\ reduced\ due\ to\ mode\ x$$

$$U_x = Number\ of\ trail\ users\ who\ travel\ by\ mode\ x, estimated\ as\ the\ total\ reduction\ in\ vehicle\ trips\ due\ to\ mode\ x\ divided\ by\ twice\ the\ number\ of\ bicycling\ and\ walking\ days\ per\ year$$

$$W = Number\ of\ weeks\ per\ year$$

$$S_x Average\ speed\ by\ mode\ x\ (mph)$$

[7] Loch Group Assumption - informed by NHTS (National Household Travel Survey) and corridor length

[8] US Army Corps of Engineers (1987). Ports on the Missouri, Arkansas, Verdigris, White, and Ouachita Rivers. Port Series No. 68.

Within Equation 3, the annual VMT reduced by bicycling and walking was calculated from the total number of vehicles diverted to a new means of transportation from Section 4.

Next, the reduction in deaths due to both bicycling and walking is estimated based on the relative mortality risk reduction due to active transportation and is calculated from **Equation 4**.

Equation 4

$$F_X = (1 - RR_X) * \left(\frac{T_X}{V_x}\right) * \frac{MR}{100{,}000 * U_X}$$

$$where:$$

$$F_X = Reduction\ in\ fatalities\ per\ year\ due\ to\ new\ trips\ by\ mode\ x$$

$$RR_X = Relative\ mortality\ risk\ associated\ with\ the\ reference\ volume\ for\ mode\ x$$

$$T_x = Minutes\ per\ week\ of\ travel\ by\ mode\ x$$

$$V_X = Reference\ volume\ for\ mode\ x\ (min\ per\ week)$$

$$MR_X = Mortality\ rate\ (deaths\ per\ 100{,}000\ people)$$

$$U_X = umber\ of\ trail\ users\ who\ travel\ by\ mode\ x, estimated\ as\ the\ total\ reduction\ in\ vehicle\ trips\ due\ to\ mode\ x\ divided\ by\ twice\ the\ number\ of\ bicycling\ and\ walking\ days\ per\ year$$

Lastly, the total avoidable deaths from Equation 4 are multiplied by the value of a statistical life in order to estimate total benefits, as shown in **Equation 5**.

Equation 5

$$Z_x = Y_x * VSL$$

$$where:$$

$$Z_x = Value\ of\ benefits\ by\ mode\ x$$

$$F_x = Reduction\ in\ deaths\ per\ year\ due\ to\ new\ trips\ by\ mode\ x$$

$$VSL = Value\ of\ a\ statistical\ life$$

5.4.3 Quality of Life Benefits

Quality of life benefits associated with reduced mortality risk due to increased physical activity from new bicyclists and pedestrians who were diverted from other modes of transportation are estimated at approximately $5,033,150 (discounted).

5.5 State of Good Repair

State of good repair benefits can be generated in two ways: (1) reduced wear and tear on the adjacent roadways due to modal diversions to walking and bicycling, and (2) reduced operations and maintenance due to a reduced roadway cross-section. The planned roadway reconfiguration along N Grand Blvd reduces the number of travel lanes from four to three, while the number of travel lanes along N Spring Ave is planned to be reduced from four to two. Less travel lanes or a smaller cross-section requires less maintenance in terms of snow removal, pavement repairs, etc.

In addition, the existing state of the roadways within the study area were documented based on available MoDOT data. MoDOT utilizes a very similar scale to the Pavement Surface Evaluation and Rating (PASER), which is summarized in **Table 10**.

Table 10. PASER Rating Scale

Quality	Rating	Treatment (Asphalt)	Treatment (PCC)
Excellent	9-10	No maintenance required	No maintenance required
Good	6-9	Crack sealing and minor patching	Routine maintenance
Fair	4-6	Preservation treatments (non-structural)	Surface repairs, partial-depth patching
Poor	2-4	Structural renewal (overlay)	Extensive slab or joint rehabilitation
Failed	1-2	Reconstruction	Reconstruction

The pavement ratings within the study area are summarized in **Table 11**. N Spring Ave did not have any available pavement condition ratings. As shown, the N Grand Blvd corridor currently has Fair to Good pavement conditions. The corridor would likely need a mill and overlay as it continues to deteriorate in the years to come.

Table 11. Pavement Ratings within Study Area

Direction	Pavement Rating (average per mile)	
	Cass Ave (Spring Ave to Grand Blvd)	N Grand Blvd (Cass Ave to Natural Bridge Ave)
Northbound	-	6.6
Southbound	-	5.3
Eastbound	6.4	-
Westbound	7	-

5.5.1 Assumptions

The state of good repairs relies heavily on the modal diversion calculation presented in Section 4. Similarly, the procedure assumes the annual 0.5 percent traffic growth rate, the average vehicle occupancy, and operating day assumptions as presented in the Travel Time Benefits from Section 5.2. The City of St. Louis provided an operational and maintenance cost of approximately $6,147 USD per lane-mile.

5.5.2 Method

In order to estimate the reduced wear and tear costs from motorists being diverted to walking or bicycling, the forecasted AADT was multiplied by the annual operating days and vehicle occupancy scale factor to determine the total number of persons traveling within the study area. The annual operation and maintenance costs along both N Grand Blvd and N Spring Ave was divided by the total people traveling along the corridor to find the annual cost per user. To estimate savings, the modal diversion estimate for the total number of diverted users along each corridor was multiplied by the annual cost per user.

Estimating the operation and maintenance savings benefits from reducing the cross-section along each corridor is fairly straightforward. Benefits are calculated by taking the difference between the between the number of lanes in the existing cross-section and those of the proposed cross-section, then multiplying by the operational and maintenance cost per lane-mile.

5.5.3 State of Good Repair Benefits

Reduced wear and tear pavement savings are added to the expected cross-section maintenance savings. The total net benefit due to state of good repair is approximately $154,833 (discounted).

6 SUMMARY OF FINDINGS

Annual costs and benefits are computed over the project lifecycle horizon and are summarized in **Table 12**. As stated previously, construction is expected to be completed with accruing project benefits by 2026. A 20-year project lifecycle is expected with final year benefits anticipated in 2046.

Table 12. Benefits-Cost-Analysis Summary

Benefit/Cost	Non-Discounted	Discounted at 7% Annually
Benefits		
Safety Benefits	$271,509,672	$105,599,674
Emission Reduction Benefits	$40,240	$21,794
Travel Time Benefits	$10,479,498	$4,078,007
Reduced Health and Mortality Benefits	$12,690,707	$5,033,150
State of Good Repair Benefits	$2,166,757	$852,944
Summary		
Net-Present-Value (NVP) of Benefits	$388,170,107	$154,984,442
Net-Present-Value (NVP) of Costs	$50,436,076	$33,625,773
Benefits-Costs-Ratio (BCR)	***4.61***	

7 SENSITIVITY ANALYSIS

As stated in the BCA Analysis Guidance, analyses of transportation infrastructure investments are subject to varying levels of uncertainty which may be attributable to preliminary cost estimates, difficulty of modeling future traffic levels, or the use of imperfect data. Performing a sensitivity analysis can help illustrate how the results from a BCA would change when various alternatives and parameters incrementally vary.

A crucial assumption within the BCA is an annual discount rate of seven percent. In order to quantify the impact of discount rate on the benefits-cost-ratio (BCR), the discount rate was varied between one and thirteen percent, while holding all other variables and assumptions constant. As shown in **Figure 4**, discount rate has minimal impact on BCR values. Even at a discount rate of thirteen percent, BCR values remain above three.

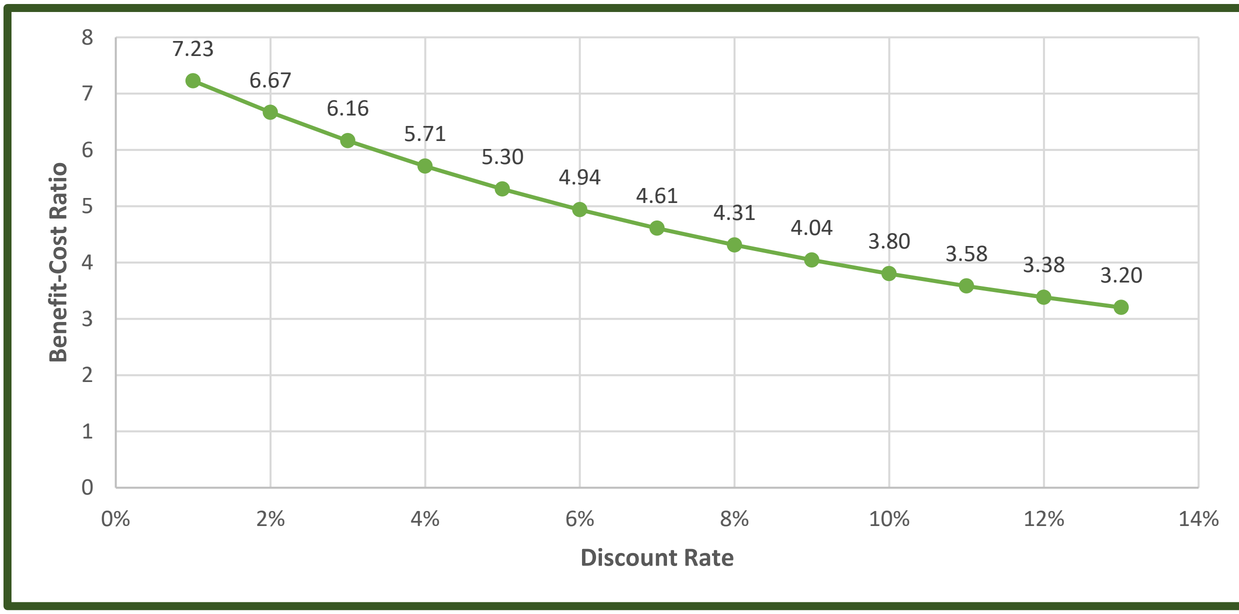

Figure 4. Discount Rate Sensitivity Analysis

The sensitivity analysis was then extended to account for variability across multiple key assumptions simultaneously. This was done in the fashion of a Monte Carlo simulation which models the probabilities of different outcomes when random variables are present. In other words, random values are assigned to variables with various levels of uncertainty and averaged over multiple simulation runs to obtain an estimate. Within the BCA spreadsheet, the Monte Carlo simulation model was developed using Visual Basic for Application (VBA).

Three variables were identified for assessment within the Monte Carlo simulation. These values were chosen as they are key drivers within the BCA and are the main parameters impacting benefits and costs.

1. Crash Analysis CMF: As stated previously, the N Grand Blvd corridor has a high number of crashes with an alarming number resulting in injuries or fatalities. Within the BCA, crash reduction benefits account for a large portion of net benefits. Hence, the applied countermeasure has a significant impact on the output of the BCA. Although the chosen countermeasures from CMF Clearinghouse were from highly reputable studies, there is a chance that the road diet countermeasure could have different results (more or less benefit) if implemented along the N Grand Blvd corridor.

2. Traffic Growth: The traffic growth rate applied in this study was informed by the East-West Gateway travel demand model for the surrounding area. Traffic growth is reliant on many variables which may be outside the scope and thus not accounted for within the travel demand model. Similarly, key methods within the BCA, such as the model diversion calculation rely on growth rate as a key input parameter. Hence, any level of uncertainty regarding traffic growth has a direct impact on BCA findings.

3. Discount Rate: Although directly provided as an assumption via from USDOT's BCA Guidance, discount rate has a direct impact on benefits and costs. Hence, discount rate was analyzed as a random variable with an unknown level of uncertainty.

Minimum and maximum values were defined for the three aforementioned variables analyzed in the Monte Carlo simulation and are summarized in **Table 13**. Each variable was assigned a random value within the minimum and maximum limits throughout each simulation run.

Table 13. Monte Carlo Simulation Parameter Limits

Parameter	Minimum Value	Maximum Value
Road Diet CMF	0.40	0.80
Traffic Growth Rate	0.1%	0.6%
Discount Rate	1%	14%

The Monte Carlo simulation was run over 1,000 replications, resulting in an average BCR of approximately 4.39 and standard deviation of approximately 1.27. Note, there was not any major deviations when increasing the replications from 1,000 to 500,000. A scatter plot and histogram of all simulation runs are depicted in **Figure 5**.

A confidence interval gives the probability that an estimated interval will contain the true value of the parameter. A 95th percent confidence interval constructed on the population mean and standard deviation of BCR values generated from the Monte Carlo simulation estimate a lower and upper bound of 4.31 and 4.47, respectively.

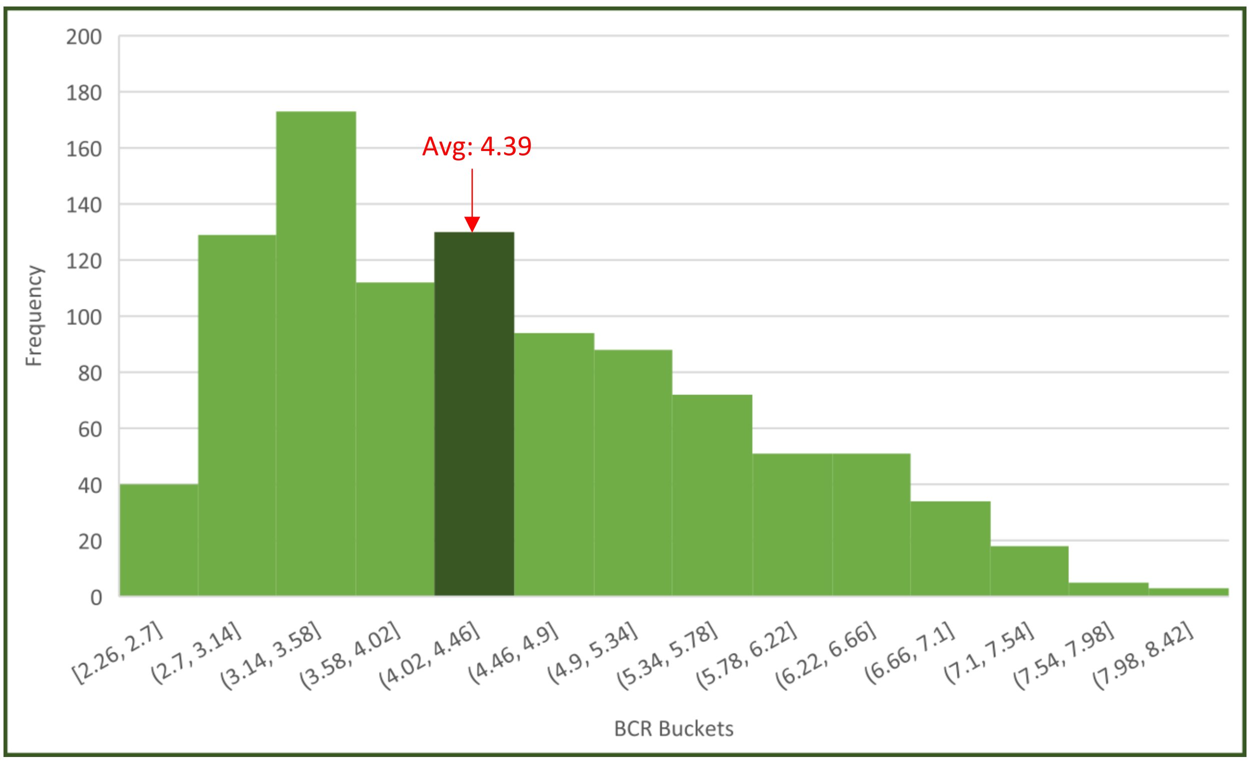

Figure 5. Monte Carlo Simulation Histogram

8 ADDITIONAL BENEFITS/ANALYSES

Within the USDOT BCA Guidance, there are several other noteworthy benefit categories which are impacted by this project but are not able to be quantified within the BCA analysis for various reasons. This section describes the relevance and notes that consideration and or attention was brought to these benefit categories, but not quantified in the BCR calculation.

8.1 Work Zone Impacts

There are no major work zone impacts expected during the construction phase of this project. Similarly, traffic detours are not anticipated, as northbound and southbound traffic will still be permitted along the corridors. Lane shifts are expected to accommodate the construction footprint and equipment. Given full-build out of the surrounding area will condense the number of through lanes along N Grand Blvd and N Spring Ave, construction traffic operations are not expected to severely worsen. However, it is likely that motorists will experience some form of delay due to construction. Increased travel times along the corridors will likely be negligible due to the increased delays.

8.2 Agglomeration Economies

The Brickline will strengthen relationships between educational, health, and cultural institutions, and local employers, creating opportunities for residents, encouraging entrepreneurship, and preparing residents for jobs in growing industries. The Brickline will directly connect residents to a job cluster towards the south of the alignment. This area includes several major St. Louis employers such as the Cortex Innovation Community, the Veterans Affairs (VA) Medical Center, St. Louis University (SLU), and the City Foundry. These job hubs offer quality jobs. Today, jobs in this cluster pay an average wage of $55,000 – more than 20% higher than the average wage for jobs located in North St. Louis. This job cluster also offers accessible jobs, as 64% of these jobs do not require a four-year college degree, making them a realistic option for the 88% of North St. Louis residents without one. This project presents an opportunity to expand opportunities for the community and contribute to local economic growth.

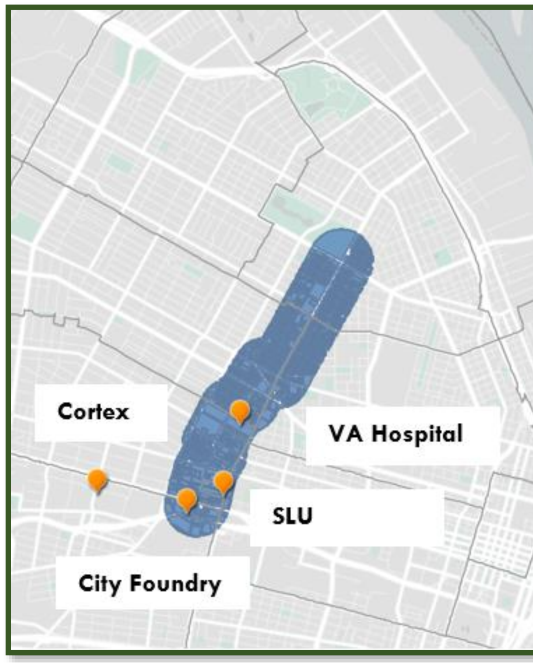

Figure 6. Nearby Job Clusters

8.3 Resiliency

Although environmental sustainability is a primary merit criterion, and this proposed project is expected to increase resiliency, the measurement and monetization of resilience benefits required too many assumptions for a reliable analysis. Some components of resiliency were captured in the BCA such as improving safety outcomes. Additionally, qualitative discussions on resiliency benefits were incorporated into the grant narrative merit criteria section. Some of the ways the project promotes social resiliency include improving health and safety outcomes, promoting social cohesion, and empowering stakeholders. The project also improves the stormwater management system. With the incorporation of street trees and Silva Cells, localized flooding is reduced, and water quality is improved.

8.4 Noise Pollution

Noise pollution is expected to be negligible upon full build out of the proposed project. It should be noted parts of the N Grand Blvd and N Spring Ave corridors are surrounded by residential housing to the east and west. Major noise level generators within the area would be contributed to the nearby roadways. The subject project is expected to divert a portion of the adjacent street traffic to pedestrian and bicycling modes of transport, which would constitute to lower noise levels. However, the monetary benefit reducing the noise pollution due to modal diversion is likely to miniscule to quantify.

8.5 Loss of Emergency Services

No major impacts are expected relative to loss of emergency services. Emergency responders will be able to utilize the corridor as they do today without needing to seek alternative routes. While the N Grand Blvd corridor may have slightly longer northbound and southbound traffic queues as a result of the implemented road diet, emergency services would be able to use portions of the two-way-left-turn-lane to bypass any queued traffic in the areas where medians do not exist. Similarly, traffic volumes along the N Spring Ave corridor are so minor that any impacts to emergency responders due to traffic delays would be negligible.

8.6 Property Value Increases

Greenways support alternate mobility options, connect to jobs and recreation, and improve neighborhood aesthetics and desirability, which in turn raise the value of nearby residential properties. Academic research provides evidence of value premiums that result from greenway investment. HR&A considered 25 peer-reviewed articles that analyze historical real estate premia associated with greenways and similar forms of park and connectivity infrastructure. From this literature review, we selected three precedents that most closely reflect the conditions of N St. Louis and the design of the Brickline – the Monon Trail in Indianapolis, IN; the Barton Creek Greenbelt in Austin, TX; and the Atlanta Beltline in Atlanta, GA. Factors included the nature of the greenway (a linear park including transportation access such as bike lanes) and a similar setting (urban, downtown adjacent). HR&A reviewed five studies that analyzed the impact of these trails and found an average one-time value increase for residential properties located within one-quarter mile of greenways to be 15%.

Using parcel data from the City of St. Louis Assessor's Office, HR&A found that the total value of the 1,346 residential parcels located within a one-quarter mile radius of the proposed Brickline alignment is $855 million, based upon the most recent County appraisal. Applying the 15% premium to the appraised value, HR&A estimates that the Brickline will increase property values by $128 million. This premium will benefit homeowners in the form of wealth creation and increase property tax revenues. Per the USDOT BCA Guidelines, though, this forecasted growth in wealth and property tax revenues was not included in the quantified BCR and would be a benefit above and beyond that calculated amount. Additional detail on the property value premium can be found in the merit criteria in the grant application.