Appendix C:

Benefit-Cost Analysis Technical Report and Excel File

Benefit-Cost Analysis Supplementary Documentation

INFRA Grant Program

I-270 North GAP Project

St. Louis, Missouri

February 25, 2020

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Benefit-Cost Analysis Supplementary Documentation

1. Executive Summary

The Benefit-Cost Analysis (BCA) conducted for this INFRA grant application compares the societal benefits associated with the proposed investment to the cost of the project. To the extent possible, benefits have been monetized. A qualitative discussion is also provided when a benefit is anticipated to be generated but is not easily monetized or quantified.

The project for which this BCA is conducted is the I-270 North Greater Access to Prosperity (GAP) Project. The project will close a major gap and eliminate a significant bottleneck along approximately 3.2 miles of Interstate 270 North (I-270 North) through suburban St. Louis, Missouri. The interstate lane configuration within the project area currently consists of two or three lanes in each direction (eastbound and westbound) with either a concrete median divider or grass median and substandard shoulders. The posted speed limit is 60 miles per hour (mph). The scope of work includes:

- Road Widening: Adding one lane in each direction on I-270 from just west of Lilac Avenue to Riverview Drive (approximately 1.25 miles); this segment is currently two lanes in each direction.
- Bridge Improvements: Replacing I-270 bridges over Route 367 (Lewis and Clark Boulevard) and over Bellefontaine Road; replacing Lilac Bridge over I-270; and rehabilitating the I-270 bridges over a BNSF railroad corridor. The Bellefontaine bridge replacement will also correct a deficient vertical clearance (currently 14’7”).
- Roadway Improvements: Widening the outside shoulder and resurfacing the existing roadway in each direction from Route 367 to Riverview Drive (3.2 miles) and 1.25 miles of new, full depth lanes.
- Transportation Systems Management Operations Strategies (TSMO): V2X (Vehicle to Everything) technology and Intelligent Transportation System (ITS) features to prevent wrong way driving, increase pedestrian safety and produce predictive analytics;
- Rehabilitating Watkins Creek Culvert which runs north/south under I-270 North approximately 0.6 miles west of the Mississippi River. The culvert is approximately 640 feet (+/-) long and runs underneath an access road on the north (Dunn Road) and both the eastbound and westbound lanes of I-270.
- Extending a shared-use trail from Route 367 to Riverview Drive (3 miles) to connect to the existing 12-mile St. Louis Riverfront Trail providing connectivity throughout the City and to Illinois bike trails via the Old Chain of Rocks Bridge.

A table summarizing the changes expected from the project and the associated benefits (discounted at 7 percent) is provided below.

Table ES-1: Summary of Infrastructure Improvements and Associated Benefits

Current Status or Baseline & Problems to Be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Benefits	Summary of Results (Discounted 2018$)
The project will close a major gap and eliminate a significant bottleneck along approximately 3.2 miles of Interstate 270 North (I-270 North) through suburban St. Louis, Missouri.	The project addresses the various concerns with the following improvements: 1) Road Widening: Adding one lane in each direction on I-270 from west of Lilac Avenue to Riverview Drive (approximately 1.25 miles). 2) Bridge Improvements: Replacing I-270 bridges over Route 367 (Lewis and Clark Boulevard) and over Bellefontaine Road; replacing Lilac Bridge over I-270; and rehabilitating the I-270 bridges over a BNSF railroad corridor.3) Roadway Improvements: Widening the outside shoulder and resurfacing the existing roadway in each direction from Route 367 to Riverview Drive (3.2 miles). 4) Transportation Systems Management Operations Strategies (TSMO) 5) Rehabilitating Watkins Creek Culvert 6) Extending a multi-use trail from Route 367 to Riverview Drive	Improved congestion and travel times due to additional capacity with road widening, allowing drivers to travel at faster speeds	Reduced Travel Time Costs	$8,161,295
		Increased vehicle operating costs from increased distances traveled due to improved connectivity from road widening, which outweighs the vehicle operating cost improvements from resurfacing the roadways	Vehicle Operating Costs	-$259,159
		Improved safety from widening the outside shoulder to improve roadway conditions and adding one lane in each direction to improve congestion	Improved Safety and Avoided Accident Costs	$24,560,291
		Increased greenhouse gas (GHG) pollution from increased distances traveled due to road widening	Emissions Costs	-$56,296
		State of good repair due to replacing and improving bridges	Residual Value of Investment	$937,294
		Improved incremental operations and maintenance (O&M) costs from bridge and roadway improvements, which outweighs the additional O&M costs from additional lane miles constructed.	Improved Incremental O&M Costs	$5,715,725
		Improved safety and reliability from TSMO	Improved reliability	N/A
		Improved connectivity from multi-use trail	Improved connectivity	N/A

The period of analysis used in the estimation of benefits and costs corresponds to 23 years, including construction and project development from 2023 to 2025 and operations from 2026 to 2045. The total (undiscounted) project costs are $39.6 million according to the distribution shown in Table ES-2. Note that the project costs were converted from 2019 dollars to 2018 dollars for the purpose of the Benefit-Cost Analysis (BCA).

Table ES-2: Summary of Project Costs, Undiscounted 2019 Dollars

Cost Category	Funding	Percent of Total Cost Financed By Source
INFRA Grant Request	$23,760,000	60%
Estimated Federal Funding	$7,920,000	20%
Estimated Non-Federal Funding	$7,920,000	20%
TOTAL	$39,600,000	100%

A summary of the relevant data and calculations used to derive the benefits and costs of the project are shown in the BCA model (in 2018 dollars). Based on the analysis presented in the rest of this document, the project is expected to generate $39.1 million in discounted benefits and $24.6 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a net present value of $14.5 million and a benefit-cost ratio of approximately 1.6.

In addition to the monetized benefits, the project would generate benefits that are difficult to quantify, such as improved connectivity and reliability.

2. Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the I-270 North GAP project:

- Section 3, Methodological Framework, introduces the conceptual framework used in the BCA;
- Section 4, Project Overview, provides an overview of the project, including a brief description of existing conditions and proposed alternatives; a summary of cost estimates and schedule; and a description of the types of effects that the I-270 North GAP project is expected to generate;
- Section 5, General Assumptions, discusses the general assumptions used in the estimation of project costs and benefits, while estimates of travel demand and traffic growth can be found in Section 6, Demand Projections;
- Specific data elements and assumptions pertaining to the long-term outcome selection criteria are presented in Section 7, Benefits Measurement, Data and Assumptions, along with associated benefit estimates;
- Estimates of the project's net present value (NPV), its benefit-cost ratio (BCR) and other project evaluation metrics are introduced in Section 8, Summary of Findings and BCA Outcomes;

- Section 9, provides the outcomes of the sensitivity analysis. Additional data tables are provided within the BCA model including annual estimates of benefits and costs to assist the U.S. Department of Transportation (U.S. DOT) in its review of the application;[1] and
- Section 10, Summary of Benefits and Costs, presents a summary table of the benefits and costs of the project.

3. Methodological Framework

The BCA conducted for this project includes the monetized benefits and costs measured using U.S. DOT guidance, as well as the quantitative and qualitative merits of the project. A BCA provides estimates of the benefits that are expected to accrue from a project over a specified period and compares them to the anticipated costs of the project. Costs include both the resources required to develop the project and the costs of maintaining the new or improved asset over time. Estimated benefits are based on the projected impacts of the project on both users and non-users of the facility, valued in monetary terms.[2]

While BCA is just one of many tools that can be used in making decisions about infrastructure investments, U.S. DOT believes that it provides a useful benchmark from which to evaluate and compare potential transportation investments.[3]

The specific methodology for this application was developed using the BCA guidance published by U.S. DOT and is consistent with the INFRA program guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the Build and No Build scenarios;
- Assessing benefits that align with those identified in the INFRA BCA guidance;
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;
- Using U.S. DOT guidance for the valuation of travel time savings, safety benefits and reductions in air emissions, while relying on industry best practice for the valuation of other effects;
- Discounting future benefits and costs with the real discount rates recommended by U.S. DOT (7 percent); and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

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[1] While the models and software themselves do not accompany this appendix, they are provided separately as part of the application.

[2] U.S. DOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2020.

[3] Ibid.

4. Project Overview

4.1 Types of Impacts

The I-270 North GAP project is expected to have significant impacts to travel time and accident costs. The additional lanes and shoulder widening will improve congestion and increase the safety of vehicles. Over the lifecycle of the analysis, **the project will save an estimated 1.5 million person hours. The project will help avoid 4 fatal collisions, 126 injury collisions, and 544 Property Damage Only (PDO) collisions.**

The project is anticipated to increase vehicle miles traveled as vehicles have better access to the interstate system, which provides faster speeds for longer trips, allowing for reduced travel times. Increased vehicle miles traveled is anticipated to increase vehicle operating costs.

4.2 Project Cost and Schedule[4]

The project will cost $38.9 million in undiscounted 2018 dollars and begin construction in 2023. Capital costs include design and engineering, right-of-way, and construction. Construction will be completed by December 2025. The incremental operations and maintenance (O&M) costs are addressed in further detail in Section 7.6, as part of the incremental O&M benefit section. The timing for costs of the project are shown in Table 1.

Table 1: Cost Summary Table, 2018 Dollars

Calendar Year	Capital Expenditures	Incremental O&M Expenditures
2023	$3,754,081	$1,370
2024	$0	$1,370
2025	$35,163,912	-$9,195,758
2026	$0	$1,370
2027	$0	$1,370
2028	$0	$1,370
2029	$0	$1,370
2030	$0	$1,370
2031	$0	$1,370
2032	$0	$1,370
2033	$0	$1,370
2034	$0	$1,370
2035	$0	$1,370
2036	$0	$1,370
2037	$0	$1,370
2038	$0	$1,370
2039	$0	$1,370
2040	$0	$1,370
2041	$0	$1,370

[4] All cost estimates in this section are in millions of discounted 2018 dollars, discounted to this year using a 7 percent real discount rate.

Calendar Year	Capital Expenditures	Incremental O&M Expenditures
2042	$0	$1,370
2043	$0	$1,370
2044	$0	$1,370
2045	$0	$1,370
Total	$38,917,993	-$9,165,611

4.3 Effects on Selection Criteria

The main benefit categories associated with the project are mapped into the economic vitality merit criteria set forth by U.S. DOT in Table 2.

Table 2: Benefit Categories and Expected Effects on Selection Criteria

Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Qualitative
Economic Vitality	Reduced Travel Time Costs	Improved congestion and travel times due to additional capacity with road widening, allowing drivers to travel at faster speeds	Yes	
	Vehicle Operating Costs	Increased vehicle operating costs from increased distances traveled due to improved connectivity from road widening, which outweighs the vehicle operating cost improvements from resurfacing the roadways	Yes	
	Improved Safety and Avoided Accident Costs	Improved safety from widening the outside shoulder to improve roadway conditions and adding one lane in each direction to improve congestion	Yes	
	Emissions Costs	Increased greenhouse gas (GHG) pollution from increased distances traveled due to road widening	Yes	
	Residual Value of Investment	State of good repair due to replacing and improving bridges	Yes	
	Improved State of Good Repair and Reduced Incremental O&M Costs	Improved incremental operations and maintenance (O&M) costs from bridge and roadway improvements, which outweighs the additional O&M costs from additional lane miles constructed.	Yes	
	Improved reliability	Improved safety and reliability from TSMO		Yes
	Improved connectivity	Improved connectivity from multi-use trail		Yes

5. General Assumptions

The BCA measures benefits against costs throughout a period of analysis beginning at the start of construction and including 20 years of operations.

The monetized benefits and costs are estimated in 2018 dollars as per U.S. DOT's BCA guidance with future dollars discounted in compliance with INFRA requirements using a 7 percent real rate.

The methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices are expressed in 2018 dollars;
- The period of analysis begins in 2023 and ends in 2045. It includes project development and construction years (2023 - 2025) and 20 years of operations (2026 - 2045);
- A constant 7 percent real discount rate is assumed throughout the period of analysis;
- Unless specified otherwise, the results shown in this document correspond to the effects of the Build alternative.

6. Demand Projections

Accurate demand projections are important to effectively estimate the benefits in a BCA. Demand projections for this project were estimated based on the VISSIM traffic demand model provided by the engineers at the Missouri Department of Transportation.

6.1 Demand Projections

The resulting weekday hourly projections from the VISSIM travel demand model are shown in Table 3.

Table 3: Regional Demand Projections

Segment		Direction	Time Period	No Build		Build	
				2018	2040	2026	2040
IS 270 - MO 367 N to Riverview Dr.	Vehicle Miles Travelled	EB	AM	12,549	19,044	12,615	18,460
			PM	25,767	30,419	24,151	29,669
		WB	AM	18,066	23,442	22,071	25,270
			PM	16,977	27,610	20,812	29,905
	Average Speed, MPH	EB	AM	63	62	63	63
			PM	62	45	61	62
		WB	AM	59	61	62	62
			PM	61	62	63	63
	Vehicle Hours Travelled	EB	AM	200	305	201	292
			PM	418	671	398	479
		WB	AM	304	384	357	406
			PM	278	444	332	475
IS 270 - Lilac Ave to Riverview Drive	Vehicle Miles Travelled	EB	AM	6,800	10,709	6,816	10,624
			PM	17,143	12,370	9,634	12,421
		WB	AM	10,834	15,192	12,946	14,977
			PM	9,390	17,479	11,519	17,421
	Average Speed, MPH	EB	AM	62	62	62	63
			PM	61	51	60	62
		WB	AM	61	60	61	62
			PM	62	62	62	63
	Vehicle Hours Travelled	EB	AM	109	173	109	168
			PM	281	245	161	200
		WB	AM	176	252	212	240
			PM	151	283	185	277
IS 270 - MO 367 N to Lilac Ave	Vehicle Miles Travelled	EB	AM	5,749	8,335	5,798	7,836
			PM	8,624	18,050	14,517	17,248
		WB	AM	7,232	8,249	9,125	10,292
			PM	7,587	10,131	9,293	12,484
		EB	AM	63	63	63	63

Segment		Direction	Time Period	No Build		Build	
				2018	2040	2026	2040
	Average Speed, MPH		PM	62	37	62	62
		WB	AM	56	63	63	62
			PM	59	63	63	63
	Vehicle Hours Travelled	EB	AM	91	132	92	124
			PM	138	484	234	278
		WB	AM	130	131	145	166
			PM	129	161	147	198

7. Benefits Measurement, Data and Assumptions

This section describes the measurement approach used for each benefit or impact category identified in Table 2 and provides an overview of the associated methodology, assumptions, and estimates. These assumptions were used in the estimation of all benefits.

Table 4: General Assumptions Used in the Benefit-Cost Analysis

Variable Name	Unit	Value	Source
Discount Rate	%	7.00%	U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2020
Project Development Begins	Year	2023	Project Schedule
Project Opens	Year	2026	
Operational Period of Analysis	Years	20	U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2020
Days in Year	Days	365	Known
Weekdays in Year	Days	261	
Feet to miles	Miles	0.000189	Standardized conversion
Length of AM peak period	Hours	2	Discussion with MoDOT technical staff
Length of PM peak period	Hours	3	
Percent Trucks	%	18.15%	Calculated from AADT and freight volumes from MoDOT's data portal
Percent Automobiles	%	81.85%	Calculated from percentage of trucks.

7.1 Travel Time Benefits

Travel time savings will be experienced by motorists through road widening on the interstate system. Traffic is able to make longer trips at higher speeds, reducing the amount of time spent on the road.

7.1.1 METHODOLOGY

Travel time savings are estimated through comparing the vehicle hours traveled (VHT) in the No Build and Build cases. The vehicle hours traveled are interpolated from the VISSIM traffic demand model and converted to person hours traveled using assumptions around average vehicle occupancy and the percentage of truck traffic. The person hours traveled is then monetized using the value of time provided in the U.S. DOT BCA guidance.

7.1.2 ASSUMPTIONS

The assumptions used in the estimation of travel time savings are summarized in Table 5.

Table 5: Assumptions Used in the Estimation of Travel Time Savings

Variable Name	Unit	Value	Source
Average Vehicle Occupancy - Auto	people/vehicle	1.67	2017 National Household Travel Survey
Average Vehicle Occupancy - Truck	people/vehicle	1.00	
Value of Time - Auto	$/hr	$16.60	U.S. DOT Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis, https://www.transportation.gov/officepolicy/transportation-policy/reviseddepartmental-guidance-valuationtravel-time-economic
Value of Time - Truck	$/hr	$29.50	

7.1.3 BENEFIT ESTIMATES

Table 6 outlines the benefits of travel time savings over the project life cycle.

Table 6: Estimates of Travel Time Savings, Millions of 2018 Dollars

	Over the Project Lifecycle	
	Constant Dollars	Discounted at 7 Percent
Travel Time Savings	$26.5	$8.2

7.2 Vehicle Operating Costs

Vehicle operating costs are anticipated to increase, as more vehicle miles traveled (VMT) are incurred in the Build case. The resurfacing of the roads should mitigate the increase in vehicle operating costs due to better ride quality from a smoother highway. Increased vehicle miles traveled will increase fuel and maintenance costs for motorists, resulting in a dis-benefit.

7.2.1 METHODOLOGY

Vehicle fuel and non-fuel operating costs are calculated based on the vehicle miles traveled. Vehicle fuel operating costs are estimated though fuel consumption rates per mile, based on average vehicle speeds. The U.S. DOT guidance provides recommendations on vehicle fuel and non-fuel operating costs on a dollar per mile basis, which is used to monetize the vehicle operating costs. The International Roughness Index (IRI) for build and no build is used to adjust the vehicle fuel and non-fuel consumption to account for the improved pavement conditions.

7.2.2 ASSUMPTIONS

The assumptions used in the estimation of vehicle operating costs are summarized in

Table 7.

Table 7: Assumptions Used in the Estimation of Vehicle Operating Costs

Variable Name	Unit	Year	Value	Source
Pavement Conditions based on International Roughness Index (IRI)				
IRI - No Build (EB)	in/mi	2023 - 2045	69	Weighted average IRI in project area, based on miles. IRI values extracted from MoDOT's ARAN Viewer. The higher the IRI, the rougher the conditions of the pavement along the segment.
IRI - No Build (WB)	in/mi	2023 - 2045	88	
IRI - Build	in/mi	2023 - 2045	55	Considered good IRI from MoDOT's pavement specialists for a new mill/fill overlay pavement treatment
Monetization of Vehicle Operating Costs				
Non-Fuel Operating Cost - Auto	$/mi	2023 - 2045	$0.32	U.S. DOT January 2020 Guidance. American Automobile Association, Your Driving Costs - 2018 Edition (2018) https://exchange.aaa.com/wp-content/uploads/2018/09/18-0090_2018-Your-Driving-Costs-Brochure_FNL-Lo-5-2.pdf
Non-Fuel Operating Cost - Truck	$/mi	2023 - 2045	$0.57	U.S. DOT January 2020 Guidance. American Transportation Research Institute, An Analysis of the Operational Costs of Trucking: 2018 Update (2018) http://truckingresearch.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf
Gasoline Retail Price	2018 $/gallon	2023	$2.07	Annual Energy Outlook 2018 Release; Gasoline sales weighted-average price for all grades. Excludes Federal, State, and Local taxes;
		2024	$2.04	
		2025	$2.07	
		2026	$2.10	
		2027	$2.13	
		2028	$2.15	
		2029	$2.19	
		2030	$2.27	
		2031	$2.30	
		2032	$2.32	
		2033	$2.38	
		2034	$2.42	
		2035	$2.46	
		2036	$2.49	
		2037	$2.51	
		2038	$2.54	
		2039	$2.58	
		2040	$2.60	
		2041	$2.62	
		2042	$2.67	
		2043	$2.70	
		2044	$2.72	
		2045	$2.77	
Diesel Retail Price	2018 $/gallon	2023	$2.40	Annual Energy Outlook 2018 Release; Gasoline sales weighted-average price for all grades. Excludes Federal, State, and Local taxes;
		2024	$2.46	
		2025	$2.48	
		2026	$2.54	
		2027	$2.55	
		2028	$2.60	
		2029	$2.64	
		2030	$2.71	
		2031	$2.75	
		2032	$2.77	
		2033	$2.83	
		2034	$2.86	

Variable Name	Unit	Year	Value	Source
		2035	$2.90	
		2036	$2.93	
		2037	$2.96	
		2038	$2.99	
		2039	$3.03	
		2040	$3.03	
		2041	$3.06	
		2042	$3.11	
		2043	$3.14	
		2044	$3.17	
		2045	$3.22	

7.2.3 BENEFIT ESTIMATES

Table 8 outlines the dis-benefits of vehicle operating costs over the project life cycle. Vehicle operating costs equate to $0.3 million in dis-benefits.

Table 8: Estimates of Vehicle Operating Costs, Millions of 2018 Dollars

	Over the Project Lifecycle	
	Constant Dollars	Discounted at 7 Percent
Vehicle Operating Costs	-$3.1	-$0.3

7.3 Improved Safety and Avoided Accident Costs

The proposed project would contribute to promoting U.S. DOT's safety long-term outcome through the improvements planned for the I-270 North GAP project. Widening the outer shoulders along Route 360 N to Riverview Drive and adding a lane in each direction on I-270 from west of Lilac Avenue to Riverview Drive will improve congestion and safety. Safety benefits represent nearly 65% of all benefits with 674 crashes avoided over the project lifecycle.

7.3.1 METHODOLOGY

The accident costs were estimated using average crash rates for the project area between 2015 and 2019. Crash data was collected for the project area between 2015 and 2019, and average collisions per year were calculated. The average vehicle miles traveled over this period were used to estimate average crash rates in the No Build case. To account for the outer shoulder widening on I-270 from Route 367 to Riverview Dr. and the additional lane in each direction between Lilac Ave and Riverview Dr., crash modification factors were applied in the Build case. Crash modification factors were selected to estimate the impact of both widening the shoulder from 10 ft. to 12 ft. and going from 4 lanes to 6 lanes.

To avoid overstating the safety benefits, the accident costs were calculated separately for vehicle miles travelled on I-270 from Route 367 N to Lilac Avenue and on I-270 from Lilac Avenue to Riverview Drive for both the Build and No Build case. This is because only shoulder widening improvements are made from Route 367 N to Lilac Avenue, while Lilac Avenue to Riverview Drive includes both roadway and shoulder widening improvements. The vehicle miles travelled were determined for all hours of the day and days of the year to be consisted with the crash rates that are based on the entire daily traffic that occurs in year.

The crash rates were then applied to the vehicle miles traveled to estimate the number of crashes. The number of fatal collisions, injury collisions, and property damage only collisions were estimated based on crash rates and were monetized through values provided by the U.S. DOT.

7.3.2 ASSUMPTIONS

The assumptions used in the estimation of improved safety and reduced accident costs are summarized in Table 9 and Table 10.

Table 9: Assumptions Used in the Estimation of Reduced Accident Costs

Variable Name	Unit	Value	Source
Daily-to-Peak Factor (EB)		2.56	Estimates based on the ratio between the peak hourly volumes from the VISSIM traffic data and AADT from the historical crash data provided by MoDOT
Daily-to-Peak Factor (WB)		2.88	
Crash Rates – No Build			
Fatal Collision Crash Rate (EB)	fatal crashes/100 million VMT	0.01	Estimates based on historical crashes in project area provided by MoDOT for the years 2015 to 2019 for both eastbound (EB) and westbound (WB) directions.
Fatal Collision Crash Rate (WB)	fatal crashes/100 million VMT	0.01	
Injury Collision Crash Rate (EB)	injury crashes/100 million VMT	0.30	
Injury Collision Crash Rate (WB)	injury crashes/100 million VMT	0.31	
Property Damage Only Collision Crash Rate (EB)	collisions/100 million VMT	1.07	
Property Damage Only Collision Crash Rate (WB)	collisions/100 million VMT	0.88	
Crash Modification **Factors** (CMF)			
Crash Modification Factor: Widen outside paved shoulder width from 10ft to 12ft for all crash types	%	77%	Average of CMF IDs 4251 and 5509 to capture benefits from widening shoulder from 10 ft. to 12 ft. for all crash types. http://www.cmfclearinghouse.org/detail.cfm?facid=4251 and http://www.cmfclearinghouse.org/detail.cfm?facid=5509
Crash Modification Factor: Widen outside paved shoulder width from 10ft to 12ft for KABC crash types	%	90%	CMF ID: 5510 to capture benefits from widening shoulder from 10 ft. to 12 ft. for KABC crash types. http://www.cmfclearinghouse.org/detail.cfm?facid=5510
Crash Modification Factor: Increase from 4 to 6 lanes for all crash types	%	85%	CMF ID: 7924 to capture benefits from additional lanes in each direction for all crash types. http://www.cmfclearinghouse.org/detail.cfm?facid=7924
Crash Modification Factor: Increase from 4 to 6 lanes for KABC crash types	%	76%	CMF ID: 7929 to capture benefits from additional lanes in each direction for KABC crash types. http://www.cmfclearinghouse.org/detail.cfm?facid=7929

Table 10: Assumptions Used in the Monetization of Reduced Accident Costs

Variable Name	Unit	Value	Source
Cost of a Fatal Collision	$/fatal collision	$10,636,600	Monetization values based on an estimate 1.09 fatalities per fatal crash, based on average of last five years of data in NHTSA's National Crash Statistics
Cost of an Injury Collision	$/injury collision	$250,600	Monetization values based on an estimate of 1.44 injuries per injury crash based on average of last five years of data in NHTSA's National Crash Statistics
Cost of a Property Damage Only (PDO) Collision	$/PDO	$4,400	The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (revised May 2015). Inflated to 2018 dollars using the GDP deflator.

7.3.3 BENEFIT ESTIMATES

Table 11 contains the monetized benefits over the life cycle of the project, split out by accident type. The improved safety and reduced accident costs obtained from the project components result in savings of $24.6 million, discounted at 7%. During the study period, 674 crashes are anticipated to be avoided.

Table 11: Estimated Reduced Accident Costs, Millions of 2018 Dollars

	Over the Project Lifecycle	
	Constant Dollars	Discounted at 7 Percent
Fatal Collision Savings	$40.1	$13.3
Injury Collision Savings	$31.6	$10.4
PDO Collision Savings	$2.4	$0.8
Total	$74.1	$24.6

7.4 Emissions Costs

The proposed project would result in an increase in vehicle miles traveled, which is expected to marginally increase emissions.

7.4.1 METHODOLOGY

Greenhouse gases (GHG) are estimated through emission rates per mile for automobiles and trucks, based on average vehicle speeds. The values are then monetized using the values provided in U.S. DOT guidance.

7.4.2 ASSUMPTIONS

The assumptions used in the estimation of avoided emissions costs are summarized in Table 12.

Table 12: Assumptions Used in the Estimation of Avoided Emissions Costs

Variable Name	Unit	Value	Source
Grams/Metric Ton	grams/metric ton	1,000,000	Standardized conversion

Variable Name	Unit	Value	Source
Carbon Dioxide Price	$/metric ton	*Varies by year*	Values based on the Preliminary Regulatory Impact Analysis for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks (July 2018). https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf. Values inflated from 2016 dollars to 2018 dollars using the GDP deflator.
Nitrogen Oxides (NOx)	$/metric ton	$9,480	The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)" https://nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf. Values are inflated from 2016 dollars to 2018 dollars using the GDP deflator.
Fine Particulate Matter (PM)	$/metric ton	$426,925	
Sulfur Oxides (SOx)	$/metric ton	$55,226	
Volatile Organic Compounds (VOC)	$/metric ton	$2,315	
CO2 Emission Rate - Auto	g/mi	*Varies by speed in year*	Estimates from California Air Resources Board, EMFAC 2014. Speed bin of 52-63 mph used to capture average speeds in project area. See BCA Model.
NOx Emission Rate - Auto	g/mi	*Varies by speed in year*	
PM Emission Rate - Auto	g/mi	*Varies by speed in year*	
SOx Emission Rate - Auto	g/mi	*Varies by speed in year*	
VOC Emission Rate - Auto	g/mi	*Varies by speed in year*	
CO2 Emission Rate - Truck	g/mi	*Varies by speed in year*	
NOx Emission Rate - Truck	g/mi	*Varies by speed in year*	
PM Emission Rate - Truck	g/mi	*Varies by speed in year*	
SOx Emission Rate - Truck	g/mi	*Varies by speed in year*	
VOC Emission Rate - Truck	g/mi	*Varies by speed in year*	

7.4.3 BENEFIT ESTIMATES

The project is estimated to increase emissions by 7,053 metric tons of CO_2 over the project life cycle, due to the increased vehicle miles traveled after the road widening. Table 13 shows the emissions costs amount to $56,296, discounted at 7%.

Table 13: Estimates of Avoided Emissions Costs, Millions of 2018 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Carbon Dioxide (CO2)	-$14,903	-$2,807
Nitrogen Oxides (NOx)	-$14,568	$2,923
Fine Particulate Matter (PM)	-$260,856	-$62,958
Sulfur Dioxide (SO2)	$19,722	$6,863
Volatile Organic Compounds (VOC)	-$1,786	-$317
Total	-$272,392	-$56,296

7.5 Residual Value of Bridges

To quantify the benefits associated with remaining service life of the bridges, the residual value of the bridges to be replaced is captured.

7.5.1 METHODOLOGY

The residual value of bridges renewed and replaced under the I-270 North GAP project for the end of the analysis period is determined as a benefit. To calculate the residual value, it is assumed that the original cost of the bridges depreciates in a linear manner over its service life.

7.5.2 ASSUMPTIONS

The assumptions used in the estimation of the residual value of the bridges are summarized in Table 14. The residual value is assessed in 2045, the final year of the 20-year period of operations.

Table 14: Assumptions Used in the Estimation of the Residual Value of Bridges

Variable Name	Unit	Value	Source
Capital Cost of Bridges	2018$	$7,942,121	Missouri Department of Transportation
Expected Life Span of Bridges - No Build	Years	20	
Expected Life Span of Bridges - Build	Years	75	

7.5.3 BENEFIT ESTIMATES

Table 15 displays the residual value of the bridges at the end of the project lifecycle. The residual value of the project is $0.9 million, discounted at 7%.

Table 15: Estimates of Residual Value of Bridges, Millions of 2018 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Incremental O&M Savings	$5.8	$0.9

7.6 Incremental O&M Costs

To quantify the benefits associated with maintaining the existing transportation network in a state of good repair, the incremental operations and maintenance costs are captured.

7.6.1 METHODOLOGY

The operations and maintenance cost savings are estimated based on the difference in costs between the No Build and Build cases. The estimates are subtracted to determine the incremental operations and maintenance costs. Negative values indicate increased operations and maintenance costs, a dis-benefit, while positive values indicate reduced operations and maintenance costs, a benefit. Due to the construction of additional lanes, annual operations and maintenance costs are anticipated to increase in the Build case. Due to the bridge and roadway improvements, rehabilitation costs are expected to decrease over the project lifecycle.

7.6.2 ASSUMPTIONS

The assumptions used in the estimation of incremental O&M costs are summarized in Table 16.

Table 16: Assumptions Used in the Estimation of Incremental O&M Costs

Variable Name	Unit	Value	Source
Bridge Rehabilitation Costs	2018$	$7,075,140	Missouri Department of Transportation
Bridge Rehabilitation Cycle	Years	15	
Bridge Rehabilitation Program - No Build	Years	5	
Pavement Rehabilitation	2018$	$2,121,988	
Pavement Rehabilitation Program - No Build	Years	5	
Pavement Rehabilitation Cycle	Years	9	
Mobility Assets	2018$	$98,280	
Annual O&M - No Build	2018$	$131,125	
Percent increase in Lane Miles - Build	%	14%	Percent change between lane miles in build and no build

7.6.3 BENEFIT ESTIMATES

Table 17 displays the state of good repair benefits over the project life cycle. The incremental operations and maintenance costs savings total $5.7 million, discounted at 7%. This is primarily due to the project's bridge and roadway improvements pushing back, and extending, the rehabilitation cycle for the bridges and pavement.

Table 17: Estimates of Incremental O&M Costs, Millions of 2018 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Incremental O&M Savings	$9.2	$5.7

8. Summary of Findings and BCA Outcomes

Table 18 and

Table 19 summarize the BCA findings. Annual costs and benefits are computed over the lifecycle of the project (23 years). As stated earlier, construction is expected to be completed in 2025. Benefits accrue during the full operation of the project (over years 2026-2045).

Table 18: Summary of Benefits, Millions of 2018 Dollars

Benefits	Constant Dollars	Discounted at 7%
Travel Time Savings	$26.5	$8.2
Vehicle Operating Cost Savings	-$3.1	-$0.3
Accident Cost Savings	$74.1	$24.6
Emission Cost Savings	-$0.3	-$0.1
Residual Value	$5.8	$0.9
O&M Cost Savings	$9.2	$5.7
Total Benefits	$112.3	$39.1

Table 19: Overall Results of the Benefit-Cost Analysis, Millions of 2018 Dollars

Project Evaluation Metric	Constant Dollars	Discounted at 7%
Total Benefits	$112.3	$39.1
Total Costs	$38.9	$24.6
Net Present Value	$73.4	$14.5
Benefit-Cost Ratio	2.9	1.6
Return on Investment (%)	189%	59%
Payback Period (years)	7.8	12.0
Internal Rate of Return (%)	10.81%	

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 10.8 percent. With a 7 percent real discount rate, the $24.6 million investment would result in $39.1 million in total benefits and a benefit-cost ratio of approximately 1.6.

9. BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on a large number of assumptions and long-term projections, both of which are subject to considerable uncertainty.

The primary purpose of the sensitivity analysis is to help identify the variables and model parameters whose variations have the greatest impact on the BCA outcomes: the “critical variables.”

The sensitivity analysis can also be used to:

- Evaluate the impact of changes in individual critical variables – how much the final results would vary with reasonable departures from the “preferred” or most likely value for the variable; and
- Assess the robustness of the BCA and evaluate, in particular, whether the conclusions reached under the “preferred” set of input values are significantly altered by reasonable departures from those values.

The sensitivity analysis was conducted with respect to changes in the length of peak periods, capital cost of the bridges, value of travel time, capital cost estimate, crash modification factors, and the length of the analysis period. The changes in the crash modification factors and capital cost estimate are the parameters that have the greatest impact on net present value.

The outcomes of the quantitative analysis for the I-270 North GAP project using a 7 percent discount rate are summarized in

Table 20 below. The table provides the percentage changes in project NPV associated with variations in variables or parameters (listed in row), as indicated in the column headers. The table demonstrates that this project features strong performance even in situations when key input values change in the direction that reduces net benefits. In all situations examined, the Benefit-Cost ratio remains above 1.

Table 20: Quantitative Assessment of Sensitivity, Summary

Parameters	Change in Parameter Value	Current NPV	New NPV	Change in NPV	New B/C Ratio
Length of Peak Periods	AM and PM peak periods are 1 hour	**$14.5 M**	$8.3 M	-42.51%	1.34
	AM and PM peak periods are 4 hours		$16.4 M	13.36%	1.67
Capital Cost of Bridges	40% Reduction in Capital Cost of Bridges		$14.1 M	-2.59%	1.57
Value of Travel Time	Low Value of Time (30% reduction in value of time)		$12.3 M	-15.34%	1.50
	High Value of Time (20% increase in value of time)		$16.1 M	11.42%	1.66
Capital Costs	25% Reduction in Capital Costs		$20.6 M	42.42%	2.12
	25% Increase in Capital Costs		$8.3 M	-42.42%	1.27
Crash Modification Factors	CMF reduction in adding lanes (10%)		$10.9 M	-24.47%	1.45
	CMF reduction in widening shoulder (10%)		$7.0 M	-51.86%	1.28
Length of Analysis Period	Increase to 30 years		$19.1 M	32.11%	1.78

10. Summary of Benefits and Costs

Table 21 presents the benefits and costs of the Project in 2018 dollars, discounted at 7 percent.

Table 21: Summary of Benefits and Costs, Discounted at 7 Percent

CY	Travel Time Savings	Vehicle Operating Cost Savings	Accident Cost Savings	Emissions Cost Savings	Residual Value	O&M Cost Savings	Total Benefits	Total Capital Costs	Net Present Value
2023	$0	$0	$0	$0	$0	-$977	-$977	$2,676,608	-$2,677,585
2024	$0	$0	$0	$0	$0	-$913	-$913	$0	-$913
2025	$0	$0	$0	$0	$0	$5,726,656	$5,726,656	$21,898,317	-$16,171,661
2026	$556,563	$165,020	$2,217,446	$2,623	$0	-$798	$2,940,854	$0	$2,940,854
2027	$538,626	$135,748	$2,061,947	$1,775	$0	-$745	$2,737,352	$0	$2,737,352
2028	$521,054	$108,946	$1,917,972	$1,003	$0	-$697	$2,548,279	$0	$2,548,279
2029	$503,854	$84,293	$1,784,641	$302	$0	-$651	$2,372,439	$0	$2,372,439
2030	$487,035	$61,794	$1,661,144	-$335	$0	-$608	$2,209,030	$0	$2,209,030
2031	$470,604	$40,978	$1,546,732	-$908	$0	-$569	$2,056,838	$0	$2,056,838
2032	$454,566	$21,913	$1,440,715	-$1,434	$0	-$531	$1,915,229	$0	$1,915,229
2033	$438,922	$4,495	$1,342,457	-$1,914	$0	-$497	$1,783,465	$0	$1,783,465
2034	$423,675	-$11,444	$1,251,370	-$2,351	$0	-$464	$1,660,786	$0	$1,660,786
2035	$408,827	-$25,916	$1,166,910	-$2,749	$0	-$434	$1,546,638	$0	$1,546,638
2036	$394,375	-$39,071	$1,088,578	-$3,096	$0	-$405	$1,440,380	$0	$1,440,380
2037	$380,318	-$50,872	$1,015,912	-$3,405	$0	-$379	$1,341,574	$0	$1,341,574
2038	$366,655	-$61,611	$948,485	-$3,676	$0	-$354	$1,249,498	$0	$1,249,498
2039	$353,382	-$71,320	$885,903	-$3,915	$0	-$331	$1,163,719	$0	$1,163,719
2040	$340,495	-$87,834	$827,803	-$6,278	$0	-$309	$1,073,876	$0	$1,073,876
2041	$327,990	-$95,139	$773,849	-$6,339	$0	-$289	$1,000,072	$0	$1,000,072
2042	$315,861	-$101,881	$723,732	-$6,381	$0	-$270	$931,062	$0	$931,062
2043	$304,104	-$107,601	$677,165	-$6,404	$0	-$252	$867,011	$0	$867,011
2044	$292,711	-$112,580	$633,884	-$6,411	$0	-$236	$807,368	$0	$807,368
2045	$281,677	-$117,077	$593,646	-$6,403	$937,294	-$221	$1,688,916	$0	$1,688,916
Total	$8,161,295	-$259,159	$24,560,291	-$56,296	$937,294	$5,715,725	$39,059,151	$24,574,925	$14,484,226

Note: CY = Calendar Year

Benefit-Cost Ratio = $39,059,151 / $24,574,925 = 1.6