Benefit-Cost Analysis Supplementary Documentation

FY2020 BUILD Grant Program

The I-49 Gateway to Kansas City

Cass County, Missouri

May 18, 2020

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Benefit-Cost Analysis Supplementary Documentation

1. Executive Summary

The I-49 Gateway to Kansas City Project will enhance system reliability, efficiency, resilience and traffic capacity throughout the I-49 corridor southeast of Kansas City by improving I-49 between 155th Street and North Cass Parkway in Cass County, Missouri. This section of I-49 is a major bottleneck in the southern portion of the bi-state Kansas City metro area – hampering regional commute traffic, vital interstate freight commerce, and travel to and from rural areas. Congestion regularly extends back for one to two miles during peak hours. The project will primarily widen the interstate from two lanes to three lanes in each direction, tying in to the six-lane configuration to the north.

A table summarizing the changes expected from the project (and the associated discounted benefits) 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 (millions of $2018)*
Congestion and Safety Concerns for Personal and Commercial Vehicles due to Bottleneck on I-49	Increase by one lane in each direction, from a total of 4 lanes to 6 lanes	Improved travel speeds, reduced congestion, reduced crash frequency, improved emergency response, and reduced effect of crash events on traffic flow.	Accident Cost Savings	$49.5
			Travel Time Savings	$15.4
			Vehicle Operating Cost Savings (Disbenefit)	($3.7)
			Emission Cost Savings (Disbenefit)	($0.05)
			Other Benefits: *(Improved travel time reliability; Inventory cost savings and freight reliability; Supporting local economic development; Improved access to local hospital)*	Non-monetized
Operation and Maintenance (O&M) of proposed infrastructure	Improved pavement conditions	Changes in operation & maintenance cost and rehabilitation costs.	O&M Cost Savings	Non-monetized

*Discounted at 7 percent.

The period of analysis used in the estimation of benefits and costs corresponds to 22 years, including 2 years of construction and 20 years of operation. The total (undiscounted) project costs are $32.7 million dollars (in 2019 dollars), which is about $32.1 million in 2018 dollars. Costs were evenly spread across the 2 years of construction.

A summary of the relevant data and calculations used to derive the benefits and costs of the project are shown in the Benefit-Cost Analysis (BCA) model (in dollars of 2018). Based on the analysis presented in the rest of this document, the project is expected to generate $61.3 million in discounted benefits and $31.0 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value of $30.2 million and a Benefit/Cost Ratio of 1.97.

Figure ES-1: Summary of Discounted Annual Benefits and Costs, Millions of 2018 Dollars

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NET PRESENT VALUE CALCULATION

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$16,049,000	($16,049,000)
2					$0	$14,999,065	($14,999,065)
Project Open							
1	$1,203,001	($287,423)	$4,015,629	($6,722)	$4,924,485	$0	$4,924,485
2	$1,143,810	($271,853)	$3,798,103	($6,370)	$4,663,689	$0	$4,663,689
3	$1,087,357	($266,732)	$3,591,852	($6,110)	$4,406,367	$0	$4,406,367
4	$1,033,529	($252,212)	$3,396,332	($5,790)	$4,171,859	$0	$4,171,859
5	$982,215	($238,451)	$3,211,021	($5,485)	$3,949,300	$0	$3,949,300
6	$933,310	($225,411)	$3,035,421	($5,197)	$3,738,123	$0	$3,738,123
7	$886,709	($213,057)	$2,869,054	($4,923)	$3,537,784	$0	$3,537,784
8	$842,315	($201,354)	$2,711,464	($1,279)	$3,351,146	$0	$3,351,146
9	$800,031	($190,270)	$2,562,213	($1,214)	$3,170,760	$0	$3,170,760
10	$759,765	($179,776)	$2,420,886	($1,152)	$2,999,724	$0	$2,999,724
11	$721,428	($169,839)	$2,287,085	($1,093)	$2,837,581	$0	$2,837,581
12	$684,935	($160,434)	$2,160,429	($1,037)	$2,683,894	$0	$2,683,894
13	$650,204	($151,532)	$2,040,557	($983)	$2,538,245	$0	$2,538,245
14	$617,155	($143,109)	$1,927,123	($933)	$2,400,236	$0	$2,400,236
15	$585,713	($135,138)	$1,819,797	($885)	$2,269,487	$0	$2,269,487
16	$555,805	($127,599)	$1,718,266	($839)	$2,145,633	$0	$2,145,633
17	$527,361	($120,467)	$1,622,231	($796)	$2,028,329	$0	$2,028,329
18	$500,314	($113,723)	$1,531,407	($755)	$1,917,243	$0	$1,917,243
19	$474,599	($107,345)	$1,445,524	($716)	$1,812,062	$0	$1,812,062
20	$450,155	($101,315)	$1,364,324	($679)	$1,712,484	$0	$1,712,484
Total	$15,439,710	($3,657,040)	$49,528,719	($52,959)	**$61,258,430**	**$31,048,065**	**$30,210,365**

1,945,964	Person-Hours of Time Saved

In addition to the monetized benefits, the project would generate benefits that are difficult to quantify. A brief description of those benefits is provided below.

Safety

- The traffic data in this BCA do not consider induced demand, and induced demand would increase the number of crashes in the project area (due to an increase in vehicle-miles on the roadway). However, a preliminary crash analysis for this project suggests that the crash reduction factors (CRFs) used in this BCA are conservative, and that planned improvements may reduce crashes by 39 to 59 percent, depending on crash severity.[1]

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[1] The project team retrieved applicable crash reduction factors (CRFs) from FHWA's CMF Clearinghouse website. It is expected that the project improvement (to increase the number of lanes from 4 lanes to 6

- Relieving the I-49 bottleneck will reduce congestion beyond the limits of the project, which will reduce crashes (especially those that occur in queues during congested conditions) on I-49 north and south of the project limits.

State of Good Repair

- The additional lane-miles are not expected to result in significant increases in maintenance costs. Further, the project will replace some or all of the existing pavement, which will decrease future maintenance costs and provide journey quality benefits to roadway users.

Economic Competitiveness

- Reducing congestion and reducing crashes on the roadway will decrease the variability of travel time through the corridor, allowing roadway users and truck drivers to reach their destination on time more consistently. Improved reliability allows drivers to reduce the amount of "buffer" time they need to budget to account for unexpected delays, which will positively impact individual roadway users, local businesses, and communities along the corridor.

lanes) would reduce fatal and injury crashes by 23.9 percent (CMF ID 7924) and property damage only (PDO) crashes by 15 percent (CMF ID 7929).

2. Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the I-49 Gateway to Kansas City 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 the proposed project; a summary of the cost estimate and schedule; and a description of the types of effects that the I-49 Gateway to Kansas City 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 estimation of benefit categories are presented in Section 7, Benefits Measurement, Data and Assumptions. 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. Next, Section 9, BCA Sensitivity Analysis, 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 (USDOT) in its review of the application.[2]

3. Methodological Framework

The BCA was primarily conducted using a modified version of the California Lifecycle Benefit/Cost Analysis Model (Cal-B/C Sketch v7.2).[3] The California Department of Transportation (Caltrans) developed the original Cal-B/C model in the mid-1990s. It has been used to evaluate capital projects proposed for the California State Transportation Improvement Program (STIP) since 1996. As part of a 2009 Cal-B/C revision, Caltrans developed a suite of tools for conducting BCAs. The Cal-B/C Sketch tool is the original model, which retains a sketch-planning format, allowing users to produce a "sketch level" BCA with constrained data and resources.

For this BCA, the standard Cal-B/C Sketch assumptions and economic values have been modified to adhere to the requirements stipulated by the USDOT. The resulting values are consistent with the guidance found in the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020). The Cal-B/C Sketch tool was used to monetize benefits with simple traffic, speed, and crash data.

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 the resources required to develop the project. Costs of maintaining the asset over time were

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

[3] California Department of Transportation (Caltrans), https://dot.ca.gov/programs/transportation-planning/economics-data-management/transportation-economics.

considered negligible for the purposes of the sketch-level BCA. Estimated benefits are based on the projected impacts of the project on users of the facility, valued in monetary terms.[4]

While BCA is just one of many tools that can be used in making decisions about infrastructure investments, the USDOT believes that it provides a useful benchmark from which to evaluate and compare potential transportation investments.[5]

The specific methodology for this application was developed using the BCA guidance published by the USDOT and is consistent with the BUILD program guidelines. In particular, and consistent with the Cal-B/C suite of tools, the methodology involves:

- Establishing existing and future conditions under the build and no-build scenarios;
- Assessing benefits with respect to each of the merit criteria identified in the Notice of Funding Opportunity (NOFO);
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;
- Using the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020) for the valuation of travel time savings, vehicle operating cost 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 the USDOT (7 percent, and 3 percent for sensitivity analysis); and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

4. Project Overview

The I-49 Gateway to Kansas City Project will enhance system reliability, efficiency, resilience and traffic capacity throughout the I-49 corridor southeast of Kansas City by improving the capacity of I-49 between 155th Street and North Cass Parkway in Cass County, Missouri.

4.1 Base Case and Alternatives

The base case, or no-build scenario, is represented as maintaining the existing conditions within the project limits. In the build scenario, the project will widen the interstate from two lanes to three lanes in each direction, tying in to the six-lane configuration to the north. The extra lanes will be developed using available space in the existing wide median, which has been planned for that purpose to provide system resilience.

4.2 Types of Impacts

The project is expected to improve travel time reliability, congestion, and safety. Based on the data, the model monetizes travel time savings, crash reduction, and changes in vehicle operating costs and emissions.

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[4] USDOT, *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*, January 2020.

[5] Ibid.

4.3 Project Cost and Schedule

A summary of the project cost breakdown is provided in Table 1. Total project costs were adjusted to 2018 dollars for use in the BCA, based on Inflation Adjustment Values published in the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020) for the year 2018.

Table 1: Summary of I-49 Project Costs

Cost Category	Undiscounted Project Cost Millions of 2019 Dollars	Undiscounted Project Cost Millions of 2018 Dollars
Engineering Costs	$4.85	$4.76
Construction Costs, including contingency	$27.83	$27.34
TOTAL COST	**$32.68**	**$32.10**

Source: Project Cost Estimate (See Appendix C).

Once the project is constructed, ongoing operations and maintenance (O&M) funding will be included as part of Missouri Department of Transportation's (MoDOT's) regular maintenance activities. These costs are not included in the BCA at this time.

The project schedule provided by the project team identified the start of construction as October of 2021, and completion of construction by the end of 2023. For the purposes of the BCA, this is simplified to a 2-year construction duration. Project costs are spread evenly across the construction duration.

4.4 Disruptions Due to Construction

Additional congestion and increased crash incidents in the construction work zone are considered in the assessment of project risks, but are not monetized in the BCA at this time due to lack of data.

4.5 Effects on Selection Criteria

The main benefit categories associated with the project are mapped to merit criteria set forth by the USDOT in Table 2.

Table 2: Benefit Categories and Expected Effects on Selection Criteria

Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
Safety	Accident Cost Savings	Reduction in fatalities, injuries, and property losses due to capacity improvements in the build scenario	Y	Y	
State of Good Repair	Pavement Condition	Replacement of pavement on existing lanes will provide necessary long-term pavement solution and reduce wear and tear on vehicles.			Y

Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
	Operations & Maintenance	Additional lane-miles are expected to result in marginal increases in overall maintenance costs.			Y
Economic Competitiveness	Travel Time Savings	Removal of the major bottleneck will reduce congestion and improve movement of people and goods.	Y	Y	
	Travel Time Reliability	Reduction in congestion and crash impacts on traffic flow will decrease travel time variability.			Y
	Vehicle Operating Cost Savings	Increase of speeds on I-49 mainline will increase fuel consumption.	Y	Y	
Environmental Sustainability	Emissions Cost Savings	Increase of speeds on I-49 mainline will change emissions.	Y	Y	

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 with future dollars discounted in compliance with BUILD 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 includes 2 years of construction and 20 years of operations;
- A constant 7 percent real discount rate is assumed throughout the period of analysis (a 3 percent real discount rate is used for sensitivity analysis); and
- Opening year demand is an input to the BCA and is assumed to be fully realized in year 1 (no ramp-up).

6. Demand Projections

Annual Average Daily Traffic (AADT) data were obtained from MoDOT's Transportation Management System.[6] Volume growth was calculated considering MoDOT AADT data from 2014-2018 and Mid-America Regional Council (MARC) future 2050 model growth rates. Table 3 summarizes the AADT and growth rates provided in support of the BCA.

[6] Available at https://datazoneapps.modot.mo.gov/bi/apps/maps/Home/Index/AADT.

Table 3: I-49 Mainline Traffic Data

	AADT Growth (Between 163rd and MO-58)						
Direction	**2019 Count Year**	**% Growth**	**2020**	**% Growth**	**2023**	**% Growth**	**2045**
Northbound	26,566	2.15%	27,137	1.09%	27,743	1.09%	35,216
Southbound	31,893		32,579		33,306		42,277
Total	**58,459**		**59,716**		**61,050**		**77,493**

Note: AADT reflects traffic on I-49 between 163rd Street and MO-58. Traffic on this section of I-49 is assumed representative of the project area for the purposes of this sketch-level analysis.

In addition to traffic levels, current speed data were provided by MoDOT staff (collected from the Regional Integrated Transportation Information System (RITIS)) for the I-49 mainline, by interstate segment and hour, to calibrate peak and non-peak speeds estimated within the Cal-B/C Sketch model.[7]

6.1 Methodology

Based on the traffic data provided, traffic levels in the project area for year 1 (2024) and year 20 (2043) of operations were estimated. For this sketch-level analysis, the same traffic levels are used to represent demand in the no-build and build scenarios; induced demand is not reflected. The project team plans to produce a robust traffic analysis to improve on the confidence and detail of traffic inputs in the near future. Once more detailed traffic data are available, the team will produce a more detailed BCA model to assess the benefits of the project.

Average speeds for peak and non-peak periods in the no-build scenario were estimated from the speed data provided, for all interstate segments within the project limits, between 155th Street and North Cass Parkway. These average speeds are used in the BCA for year 1 in the no-build scenario to more accurately represent the current state of congestion on the interstate. Speeds for year 20 in the no-build scenario, which are initially approximated by the Cal-B/C Sketch tool, are adjusted based on the ratio between current average speeds and the model's approximated speeds for no-build scenario year 1.

6.2 Assumptions

Table 4 lists the primary assumptions that informed the traffic demand model inputs. The project length is used to estimate average crash rates and vehicle-miles traveled. The peak period is assumed to occur from 7 am to 8 am and 4 pm to 6 pm, which informs the estimation of speeds in the no-build scenario for peak and non-peak periods from the hourly speed data. The Cal-B/C Sketch tool estimates that 25 percent of Average Daily Traffic (ADT) occurs during the peak period, based on the length of the peak period (3 hours) and the interstate capacity. The number of lanes (for both directions) in the no-build and build scenarios are used in the Cal-B/C Sketch

[7] The Cal-B/C Sketch tool calculates speeds internally based on the capacity of the roadway and the peak versus non-peak traffic. The user can override these calculated speeds based on more detailed project data, if available.

tool's internal estimation of speeds, and free-flow speed is the maximum cap on speed in all scenarios.

Table 4: Assumptions Used in the Estimation of Demand

Variable Name	Unit	Value	Source
Project Length	miles	4.21	Project Length measurement.
Length of Peak Period	hours	3	Based on 2017 hourly traffic count data provided by MoDOT and interchange turning movement counts provided by StreetLight Data, Inc.
Interstate Capacity	vehicles per hour per lane	2,000	Project team estimate for I-49.
Number of Lanes in the no-build scenario	lanes	4	Existing conditions.
Number of Lanes in the build scenario	lanes	6	Project build conditions.
Free Flow Speed	miles per hour	67	Average of speed limits in the project area, weighted by approximate project length (miles).
Truck Speed	miles per hour	55	Conservative assumption.

6.3 Demand Projections

The resulting model inputs for ADT and speeds in year 1 and year 20 of operation, and in the peak and non-peak periods, are presented in Table 5. Traffic volumes and growth are assumed the same in the no-build and build scenarios; there is no induced demand for the purposes of this analysis. Induced demand will be considered when detailed traffic analysis for the project can be completed.

Table 5: Traffic Demand and Speed Model Inputs

	No-Build Scenario		Build Scenario	
	Year 1	Year 20	Year 1	Year 20
Peak Traffic Volume	15,429	18,958	15,429	18,958
Non-Peak Traffic Volume	46,287	56,874	46,287	56,874
Peak Speed (mph)	60.1	59.1	67.0	67.0
Non-Peak Speed (mph)	65.6	65.6	67.0	67.0

7. Benefits Measurement, Data, and Assumptions

Using the modified version of the Cal-B/C Sketch tool and the data available, four primary categories of user benefits were quantified and monetized for the project according to the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020).

- **Accident cost savings.** The proposed project improvements are expected to decrease the incidence of crashes within (and beyond) the project limits through increased capacity and relieved congestion.
- **Travel time savings.** Capacity improvements will lead to increases in speeds on the mainline due to less congestion, resulting in monetized travel time savings. The project is expected to save approximately 1.95 million person-hours over 20 years. Additional benefits (not monetized in this BCA) would accrue from fewer crash-related disruptions to traffic flow and an increase in travel time reliability for roadway users.
- **Vehicle operating cost savings.** The increase in speeds leads to less efficient levels in terms of fuel consumption rates. The resulting changes in vehicle operating costs amount to a relatively small disbenefit to the project.
- **Emission reductions.** The increase in speeds also leads to less efficient levels in terms of emission rates. Similarly, the resulting changes in emissions amount to a relatively small disbenefit to the project.

This section describes the measurement approach used for each benefit category and provides an overview of the associated methodology and assumptions.

7.1 Methodology

The methodology used for estimating each of the benefit categories is presented below.

Accident Cost Savings. The anticipated crash reduction from increasing capacity from 4 to 6 lanes is applied to historical crash rates to derive safety benefits. Historical crash data for the project area was provided by MoDOT staff, sourced from MoDOT's Transportation Management System. Three-year crash totals, by crash severity, were summarized and used as model input.[8] Crash totals are converted to crashes per million vehicle miles (MVM) with ADT and project length. Crashes avoided, by severity, are calculated from crashes per MVM and crash reduction factors, sourced from FHWA's CMF Clearinghouse database, and then monetized using dollar per crash estimates. Dollar per crash estimates are derived from statewide three-year historical crash statistics (events per crash and the distribution of crashes, by severity) and monetization factors (dollars per event, by severity) from the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020). Due to the constraint on resources related to the COVID pandemic, the project team was unable to find appropriate crash statistics for Missouri. Crash statistics from the state of Minnesota are used as a proxy. A sensitivity test using the Cal-B/C defaults for rural projects was performed and there was no significant difference in the BCA results. The Cal-B/C Sketch tool uses the same crash rate in the current and future year by default, and the number of crashes increases commensurately with the traffic volumes.

Travel Time Savings. Travel time benefits are calculated based on traffic volumes, speed, and project length for year 1 and year 20, for the no-build and build scenarios. The percent truck traffic (based on project-specific data) is used to separate personal vehicle volumes from truck volumes in peak and non-peak periods. The average vehicle occupancy (AVO) values included in the

[8] The three most recent years of data available (2016 to 2018) were used.

USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020) are used for the purposes of this analysis. The model multiplies the number of hours saved by personal and commercial vehicle drivers by their corresponding AVO values and values of time. Travel time costs are compared between the no-build and build scenarios and the difference is the travel time savings.

Vehicle Operating Cost Savings. The same traffic volumes and speed used to calculate travel time savings are used to calculate vehicle operating cost savings, which consist of fuel and non-fuel costs for personal and commercial vehicles. In the BCA model, average speed is used to determine fuel consumption per mile for personal and commercial vehicles, and vehicle miles traveled (VMT) is calculated from traffic volumes and the project length. Fuel costs are calculated by multiplying fuel consumption per mile, VMT, and fuel price for the no-build and build scenarios. Fuel consumption associated with the build scenario speeds is greater than consumption associated with the no-build scenario speeds; thus, the calculation results in a disbenefit. Non-fuel cost is calculated by multiplying VMT and non-fuel per mile cost (which accounts for maintenance and other vehicle costs).[9] The fuel and non-fuel costs are compared between the no-build and build scenarios, and the difference is the vehicle operating cost savings.

Emissions Cost Savings. There are five types of emissions measured in the analysis: carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxide (NO_x), fine particulate matter (PM2.5), sulfur dioxide (SO_2), and carbon dioxide (CO_2). For this BCA, emissions per mile travelled for these pollutants are estimated using the default emission rates in the Cal-B/C Sketch tool. Emissions are monetized using dollar per U.S. short ton values based the parameters in the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020).

7.2 Assumptions

The data and assumptions used in the estimation of economic benefits for the project are summarized in Tables 6 to 9.

Table 6 summarizes the crash rates and event per crash rates estimated from the crash data, as well as the monetization factors and crash reduction factors used to estimate safety benefits.

[9] Since traffic volumes and miles traveled are the same between the no-build and the build scenarios, non-fuel cost savings are equal to zero.

Table 6: Data and Assumptions Used in the Estimation of Safety Benefits

Variable Name	Unit	Value	Source
Annual Fatal Accident Rate	fatal accidents per MVM	0.011	Analysis of project specific historical crash data from MoDOT's Transportation Management System.
Annual Injury Accident Rate	injury accidents per MVM	0.45	
Annual PDO Accident Rate	PDO accidents per MVM	1.24	
Average Number of Fatalities per Fatal Crash	fatalities per crash	1.08	Analysis of Minnesota Motor Vehicle Crash Facts, 2016-2018, Minnesota Department of Public Safety, Office of Traffic Safety.[10]
Average Number of Injuries per Fatal Crash[11]	injuries per crash	0.95	
Average Number of Vehicles per Fatal Crash	vehicles per crash	1.62	
Average Number of Injuries per Injury Crash	injuries per crash	1.36	
Average Number of Vehicles per Injury Crash	vehicles per crash	1.85	
Average Number of Vehicles per PDO Crash	vehicles per crash	1.85	
Crash Reduction Factor (Fatal and Injury Crashes)	percentage	23.9%	Park et al., 2015 found in CMF Clearinghouse, CMF IDs 7924 and 7929, http://www.cmfclearinghouse.org/
Crash Reduction Factor (PDO Crashes)	percentage	15%	
Fatality Cost	dollars per fatality	$9,600,000	USDOT, *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*, January 2020.
Incapacitating Injury Cost	dollars per injury	$459,100	
Non-incapacitating Injury Cost	dollars per injury	$125,000	
Possible Injury Cost	dollars per injury	$63,900	
Property Damage Only (PDO) Crash Cost	dollars per damaged vehicle	$4,400	

[10] The project team attempted and were unable to find crash statistics for the state of Missouri, due to the constraints on resources related to the COVID-19 pandemic. Crash statistics from the state of Minnesota are used as a proxy. If the Cal-B/C Sketch tool's default values for projects in rural areas were used, the benefit-cost ratio would remain at 1.97 and the accident cost savings would decrease by $0.1M.

[11] Cal-B/C Sketch tool default parameter for the average number of injuries per fatal crash was used for this analysis, as the Minnesota Crash Statistics Report did not specify injuries in fatal crashes. The average

The assumptions used in the estimation of travel time savings are summarized in Table 7.

Table 7: Assumptions Used in the Estimation of Travel Time Savings

Variable Name	Unit	Value	Source
Peak Average Vehicle Occupancy	persons per vehicle	1.5	USDOT, *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*, January 2020.
Non-Peak Average Vehicle Occupancy	persons per vehicle	1.7	
Auto Value of Time	dollars per hour	$16.60	
Truck Value of Time	dollars per hour	$29.50	
Truck Percentage of Traffic	percentage	16%	Weighted average of truck percentages on I-49 mainline, Data from MoDOT's Transportation Management System.
Annualization Factor for Vehicle Trips	days per year	365	Corresponding to AADT data.

The assumptions used in the estimation of vehicle operating cost savings are summarized in Table 8.

Table 8: Assumptions Used in the Estimation of Vehicle Operating Cost Savings

Variable Name	Unit	Value	Source
Fuel Cost (Retail Gasoline) – Automobiles	dollars per gallon	$2.07	U.S. Energy Information Administration (EIA) Annual Energy Outlook. Net of federal and state taxes.
Fuel Cost (Retail Diesel) – Trucks	dollars per gallon	$2.31	
Vehicle Operating Non-Fuel Cost– Automobiles	dollars per mile	$0.32	HDR computation based on the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020).
Vehicle Operating Non-Fuel Cost – Trucks	dollars per mile	$0.57	
Truck Percentage of Traffic	percentage	16%	Weighted average of truck percentages on I-49 mainline, Data from MoDOT's Transportation Management System.
Annualization Factor for Vehicle Trips	days per year	365	Corresponding to AADT data.

number of injuries per injury crash was subsequently calculated from the statewide three-year historical injuries and injury crashes assuming 0.95 injuries per fatal crash.

The assumptions used in the estimation of emissions benefits are summarized in Table 9.

Table 9: Assumptions Used in the Estimation of Emissions Benefits

Variable Name	Unit	Value	Source
Volatile Organic Compounds (VOC)	Dollars per short ton	$2,100	HDR computation based on the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020). Cost of CO_2 varies by year.
Nitrogen Oxides (NO_x)	Dollars per short ton	$8,600	
Fine Particulate Matter (PM)	Dollars per short ton	$387,300	
Sulfur Dioxide (SO_2)	Dollars per short ton	$50,100	
Carbon (CO_2)	Dollars per short ton	$0.91-$1.81	

8. Summary of Findings and BCA Outcomes

The tables below summarize the BCA findings. Annual costs and benefits are computed over the lifecycle of the project (22 years). As stated earlier, construction is expected to be completed by the end of 2023. Benefits accrue during the full operation of the project.

Table 10: Overall Results of the Benefit Cost Analysis, Millions of 2018 Dollars*

Project Evaluation Metrics	7% Discount Rate
Total Discounted Benefits	$61.3
Total Discounted Costs	$31.0
Net Present Value	$30.2
Benefit / Cost Ratio	1.97
Internal Rate of Return (%)	16.5%
Payback Period (years)	6 years

*Unless specified otherwise.

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 16.5 percent. With a 7 percent real discount rate, the $31.0 million investment would result in $61.3 million in total benefits and a Benefit/Cost ratio of approximately 1.97.

Table 11: Benefit Estimates by Category for the Build Scenario, Millions of 2018 Dollars

Benefit Categories	In Constant Dollars	7% Discount Rate
Accident Cost Savings	$102.5	$49.5
Travel Time Savings	$32.3	$15.4
Vehicle Operating Cost Savings	($7.6)	($3.7)
Emissions Cost Savings	($0.1)	($0.1)
Total Benefit Estimates	**$127.1**	**$61.3**

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 outcomes of the quantitative analysis for the I-49 Gateway to Kansas City Project are summarized in Table 12. The first row presents results that correspond with those in Section 8, Summary of Findings and BCA Outcomes. Unless otherwise specified, the results correspond with a 7 percent discount rate. The table provides the percentage changes in project NPV associated with changes in variables or parameters (listed in row), as indicated in the column headers.

Table 12: Quantitative Assessment of BCA Sensitivity

Parameters	Change in Parameter Value	NPV	Change in NPV	B/C Ratio
Base Results	**No change in parameters.**	**$30.2**	**0%**	**1.97**
Discount Rate	Results discounted by 3%.	$59.1	96%	2.87
Induced Demand	Induced demand from project improvement increases traffic in build scenario by 5%.	($1.2)	-104%	0.96
Crash Reduction Factor	Overall crash reduction of 34%, coinciding with preliminary crash analysis.[12]	$53.8	78%	2.73
Induced Demand & Crash Reduction Factor	Increase in build scenario traffic by 5% and crash reduction of 34%.	$23.5	-22%	1.76
Capital Cost Estimate	Project costs increased by 20%.	$24.0	-21%	1.64
Value of Travel Time	Lower Bound of Range Recommended by USDOT ($11.80 per hour for autos and $23.58 per hour for trucks).	$25.7	-15%	1.83
	Upper Bound of Range Recommended by USDOT ($19.97 per hour for autos and $35.42 per hour for trucks).	$33.3	10%	2.07
Value of Statistical Life	Lower Bound of Range Recommended by USDOT ($5.4 million).	$17.9	-41%	1.58
	Upper Bound of Range Recommended by USDOT ($13.4 million).	$41.2	36%	2.33
Crash Statistics	Use of Cal-B/C default parameters for event per crash and crash distribution by severity in rural projects.	$30.1	0%	1.97

[12] Presented in Table IV-2 of the FY2020 BUILD Grant Application for the I-49 Gateway to Kansas City Project.