Appendix B:

Benefit-Cost Analysis

Supplementary Documentation for Revised Benefit-Cost Analysis

FY2020 BUILD GRANT APPLICATION

The I-49 Gateway to Kansas City: Building Reliability for Today and Tomorrow

Raymore, Missouri

July 15, 2020

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1. Supplementary Documentation for Revised Benefit-Cost Analysis 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.

The original preliminary Benefit-Cost Analysis (BCA) submitted with this grant application was performed using the Cal-B/C Sketch model and the traffic and safety data available. After the Traffic Analysis and Safety Analysis for the project (described in Appendix E of the application) were completed, and the project schedule was revised, the BCA was updated and improved. This updated BCA was completed in Cal-B/C Corridor model, as its input options allow for more detailed calculations of travel time savings and accident cost savings. A table summarizing the changes to the baseline expected from the project (and the associated discounted benefits) is provided below. The table provides a summary of both the preliminary BCA results submitted with the application and the revised BCA results.

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	Preliminary Results (millions of $2018)*	Revised 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	$41.6
			Travel Time Savings	$15.4	$56.5
			Vehicle Operating Cost Savings (Disbenefit)	($3.7)	($8.5)
			Emission Cost Savings (Disbenefit)	($0.1)	($0.3)
			Other Benefits: *(Improved travel time reliability; Inventory cost savings and freight reliability; Local economic development support; Improved access to local hospital)*	Non-monetized	Non-monetized
Operation and Maintenance (O&M) of proposed infrastructure	Increased number of lanes	Changes in O&M cost and rehabilitation costs.	O&M Cost Savings (Disbenefit)	Non-monetized	($0.1)

*Discounted at 7 percent.

This document reports the results of the revised model, as described above, and identifies key differences between the original (Preliminary Model) BCA and the updated (Revised Model) BCA.

The period of analysis used in the estimation of benefits and costs corresponds to 23 years, including 27 months (across 3 calendar years) of construction and 20 years of operation. The total (undiscounted) project costs are $32.7 million (in 2019 dollars), which is about $32.1 million in 2018 dollars. Costs were evenly spread across the 27 months of construction, starting in October 2021 and ending in December 2023. The Preliminary Model used a different project schedule that assumed an earlier start of construction and was spread over two years rather than three.

A summary of the relevant data and calculations used to derive the benefits and costs of the project are shown in the Revised Benefit-Cost Analysis (BCA) Model (in 2018 dollars) and Figure ES-1. Based on the analysis presented in the rest of this document, the project is expected to generate $89.2 million in discounted benefits and $24.0 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value of $65.2 million and a Benefit/Cost Ratio of 3.72 in the Revised Model.

The Preliminary Model had $31.0 million in discounted costs (mainly due to the fact that the cost was discounted relative to the first year of construction in that model, rather than to 2018, but also due to the earlier start of construction). The discounted total benefit from the Preliminary Model was estimated at $61.3 million, resulting in the original Benefit/Cost Ratio of 1.97.

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

Year	PRESENT VALUE OF USER BENEFITS (location 1)					Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Operation & Maintenance Cost Savings			
Construction Period								
2021						$0	$2,911,277	($2,911,277)
2022						$0	$10,883,295	($10,883,295)
2023						$0	$10,171,304	($10,171,304)
2024						$0	$0	$0
2025						$0	$0	$0
2026						$0	$0	$0
2027						$0	$0	$0
2028						$0	$0	$0
Project Open								
2024	$2,705,865	($240,725)	$3,048,476	($17,653)	($8,715)	$5,487,247	$0	$5,487,247
2025	$2,809,593	($301,567)	$2,927,970	($22,166)	($8,145)	$5,405,685	$0	$5,405,685
2026	$2,890,069	($349,674)	$2,810,184	($22,972)	($7,612)	$5,319,995	$0	$5,319,995
2027	$2,949,741	($386,060)	$2,695,279	($23,530)	($7,114)	$5,228,316	$0	$5,228,316
2028	$2,990,850	($412,863)	$2,583,380	($23,848)	($6,648)	$5,130,871	$0	$5,130,871
2029	$3,015,443	($433,205)	$2,474,587	($24,109)	($6,213)	$5,026,504	$0	$5,026,504
2030	$3,025,389	($451,579)	$2,368,973	($24,478)	($5,807)	$4,912,499	$0	$4,912,499
2031	$3,022,392	($458,701)	$2,266,586	($12,004)	($5,427)	$4,812,847	$0	$4,812,847
2032	$3,008,004	($468,106)	$2,167,456	($11,631)	($5,072)	$4,690,652	$0	$4,690,652
2033	$2,983,638	($473,114)	$2,071,596	($11,295)	($4,740)	$4,566,085	$0	$4,566,085
2034	$2,950,576	($474,515)	$1,979,003	($10,978)	($4,430)	$4,439,656	$0	$4,439,656
2035	$2,909,984	($469,617)	$1,889,658	($10,506)	($4,140)	$4,315,380	$0	$4,315,380
2036	$2,862,918	($466,837)	$1,803,533	($10,155)	($3,869)	$4,185,590	$0	$4,185,590
2037	$2,810,333	($459,627)	$1,720,590	($9,625)	($3,616)	$4,058,055	$0	$4,058,055
2038	$2,753,093	($458,756)	$1,640,780	($9,413)	($3,380)	$3,922,324	$0	$3,922,324
2039	$2,691,975	($449,692)	$1,564,048	($9,083)	($3,159)	$3,794,089	$0	$3,794,089
2040	$2,627,681	($440,023)	$1,490,334	($8,688)	($2,952)	$3,666,353	$0	$3,666,353
2041	$2,560,842	($430,903)	$1,419,571	($8,373)	($2,759)	$3,538,378	$0	$3,538,378
2042	$2,492,021	($424,275)	$1,351,689	($8,094)	($2,578)	$3,408,762	$0	$3,408,762
2043	$2,421,723	($409,785)	$1,286,612	($7,660)	($2,410)	$3,288,480	$0	$3,288,480
Total	$56,482,131	($8,459,624)	$41,560,305	($286,259)	($98,786)	**$89,197,767**	**$23,965,877**	**$65,231,891**

In addition to the monetized benefits, the project would generate other benefits that are difficult to quantify. A brief description of those benefits is provided below.[1]

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.

[1] The Preliminary Model did not quantify safety benefits associated with induced demand due to limited traffic data at the time, and it also did not monetize the disbenefits from increased O&M costs (part of the State of Good Repair criterion). The Revised Model incorporates both components in benefit calculations.

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 Preliminary BCA Model is conducted using a modified version of the California Lifecycle Benefit/Cost Analysis Model (Cal-B/C Sketch v7.2). For the Revised Model, Cal-B/C Corridor v7.2 was used.[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. The Cal-B/C Corridor tool was added later and allows for more detailed analysis using vehicle-miles traveled (VMT) and vehicle-hours traveled (VHT) as primary inputs to estimate most benefit categories. The version used for this analysis also includes accident cost savings as part of the benefits calculated by default.[4]

For this BCA, the standard Cal-B/C 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). For the Revised Model, the Cal-B/C Corridor tool was used to monetize

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[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.

[4] Prior versions of Cal-B/C Corridor did not include this benefit category and the users had to create their own version of accident cost savings calculations and integrate these calculations into the model.

benefits with VMT, VHT, and crash data acquired through the Traffic and Safety Analyses conducted by the HDR team, included in Appendix E of the application.

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 considered negligible for the purposes of the Preliminary Model, but have been captured in the Revised Model. Estimated benefits are based on the projected impacts of the project on users of the facility, valued in monetary terms.[5]

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.[6]

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; and
- Discounting future benefits and costs with the real discount rates recommended by the USDOT (7 percent).

The Preliminary Model incorporates a sensitivity analysis for the assessment of the impacts of changes in key estimating assumptions. The project team feels that this analysis is sufficient and therefore did not perform sensitivity analysis in the Revised Model.

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

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

[6] Ibid.

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.

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. In the Revised Model, these costs are modeled as disbenefits, described further in Section 7.

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. In the Preliminary BCA Model, this was simplified to a 2-year construction duration. However, the duration and timing for construction is modeled in greater detail in the Revised Model, over a period of 27 months. Costs are spread proportionately across years by the number of months that construction occurs in each year.

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
	Operations & Maintenance	Additional lane-miles are expected to result in marginal increases in overall maintenance costs.	Y	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 3 years of construction and 20 years of operations;
- A constant 7 percent real discount rate is assumed throughout the period of 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

For the Revised Model, the project team utilized data from the Traffic Analysis performed for the I-49 project (described in Appendix E of the application). **Error! Reference source not found.** summarizes the resulting peak-hour (daily) numbers of trips provided in support of the BCA. Trips are summarized for two forecast years (2023 and 2045), two scenarios (no-build and build), and two peak periods (AM and PM).

Table 3: Project Traffic Data

Average Daily Trips								
Year	**2023**				**2045**			
Scenario	**No-Build**		**Build**		**No-Build**		**Build**	
Period	AM	PM	AM	PM	AM	PM	AM	PM
Northbound	8,361	5,408	8,360	5,408	9,153	6,989	10,403	6,989
Southbound	3,829	11,099	3,829	11,334	4,775	10,771	4,775	14,125
Total	**12,190**	**16,507**	**12,189**	**16,742**	**13,927**	**17,760**	**15,178**	**21,113**

6.1 Methodology

The Preliminary Model relied on Annual Average Daily Traffic (AADT) data obtained from MoDOT's Transportation Management System. Volume growth was calculated considering MoDOT AADT data from 2014-2018 and Mid-America Regional Council (MARC) future 2050 model growth rates, and the same traffic levels were used to represent demand in the no-build and build scenarios (induced demand was not reflected). Average peak and non-peak period speeds estimated within the Preliminary Model (Cal-B/C Sketch) were calibrated using current speed data provided by MoDOT staff (collected from the Regional Integrated Transportation Information System (RITIS)) for the I-49 mainline, by interstate segment and hour.

For the Revised BCA Model, the HDR project team produced a robust traffic analysis model for the I-49 project (see the Traffic Analysis in Appendix E) to improve on the confidence and detail of the traffic inputs (VMT and VHT). These traffic inputs, for each scenario and forecast year, by roadway segment, peak period, and direction, represent current and future traffic demand with and without the project in the Revised BCA Model. The BCA metrics from the Revised Model are thus an improved evaluation of the project's benefits compared to those from the Preliminary Model because the traffic data are more robust and provided in greater detail.

6.2 Assumptions

Table 4 lists the primary assumptions that informed the traffic demand model inputs. The Revised Model uses the data from the Traffic Analysis, described above, as model inputs for the Cal-B/C Corridor tool. The assumptions listed in the table were used by the traffic analysts and are not entered into the Revised BCA Model directly.

Table 4: Assumptions Used in the Estimation of Demand

Variable Name	Unit	Value	Source
Project Length, Southbound	miles	5.7	Traffic operations model.
Project Length, Northbound	miles	6.2	Traffic operations model.
Number of Lanes in the no-build scenario	lanes	4	Existing conditions.
Number of Lanes in the build scenario	lanes	6	Project build conditions.

As for the Preliminary Model, it relied on these and other assumptions, including project length, to estimate average crash rates and VMT, interstate capacity and peak period duration to inform the estimation of speeds in the no-build scenario, and free-flow speed to estimate speeds in the build scenario. For the Preliminary Model, the Cal-B/C Sketch tool estimated the percent of Average Daily Traffic (ADT) that would occur during the peak period, based on the length of the peak period and the interstate capacity. The number of lanes (for both directions) in the no-build and build scenarios were used in the Cal-B/C Sketch tool's internal estimation of speeds, and free-flow speed was the maximum cap on speed in all scenarios.

6.3 Demand Projections

Table 5 shows the projections for VMT, VHT, and speed used in the Revised Model, summarized for two forecast years (2023 and 2045), two scenarios (no-build and build), and two peak periods (AM and PM). In the Preliminary Model, traffic volumes and growth were assumed to be the same in the no-build and build scenarios; there was no induced demand in that analysis. However, induced demand is considered in the Revised Model based on the data from the Traffic Analysis.

Table 5: Traffic Demand and Speed Model Inputs

Daily Peak-Period VMT								
Year	**2023**				**2045**			
Scenario	**No-Build**		**Build**		**No-Build**		**Build**	
Period	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
Northbound	51,958	33,606	51,950	33,606	56,875	43,427	64,646	43,427
Southbound	21,729	62,990	21,729	64,322	27,098	61,130	27,098	80,162
Total	**73,687**	**96,595**	**73,679**	**97,928**	**83,973**	**104,557**	**91,744**	**123,590**

Daily Peak-Period VHT								
Year	**2023**				**2045**			
Scenario	**No-Build**		**Build**		**No-Build**		**Build**	
Period	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
Northbound	1,025	525	806	518	2,371	690	1,034	670
Southbound	343	1,304	338	1,008	428	1,474	422	1,276
Total	**1,367**	**1,829**	**1,144**	**1,526**	**2,799**	**2,164**	**1,456**	**1,945**

Peak-Period Speed								
Year	**2023**				**2045**			
Scenario	**No-Build**		**Build**		**No-Build**		**Build**	
Period	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
Northbound	50.7	64.0	64.5	64.9	24.0	62.9	62.5	64.9
Southbound	63.4	48.3	64.3	63.8	63.3	41.5	64.2	62.8

7. Benefits Measurement, Data, and Assumptions

Using the modified version of the Cal-B/C Corridor tool and the data available, five primary categories of user benefits were quantified and monetized for the project in the Revised BCA Model 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 9.3 million person-hours over 20 years. Additional time savings (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 from 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 from the project.
- **Operation & Maintenance Cost Savings.** The increase in the number of lanes in each direction is associated with an increase in O&M costs and cost of repair (a disbenefit).

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 Revised Model relies on the Safety Analysis performed for the I-49 project, described in Appendix E of the application. The Safety Analysis provides annual crashes for both no-build and build scenarios, for 2023 and 2045. Thus, no additional crash reduction factors are required. Annual numbers of crashes were entered into Cal-B/C Corridor tool as model input and did not require conversion to rates per million vehicle miles (MVM). Dollar-per-crash estimates are derived from Missouri statewide crash statistics (events per crash)[7] and monetization factors (dollars per event, by severity) from the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020).

In the Preliminary Model, the anticipated crash reduction from increasing capacity from 4 to 6 lanes was 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. Crash reduction factors for the Preliminary Model were sourced from FHWA's CMF Clearinghouse database, and then monetized using dollar per crash estimates. 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.

The Revised Model uses the number of trips, VMT, and VHT data from the Traffic Analysis, entered into the Cal-B/C Corridor tool for each "modeling group". There are 15 physical (geographical) segments in the Northbound direction and 16 in the Southbound direction, for the total of 31 segments. There are two peak periods (AM and PM) for each of these 31 segments. Thus, the Revised Model uses 62 modeling groups. Each modeling group has a percentage of trucks (commercial vehicles) in the traffic associated with it (based on the traffic model outputs). Average Vehicle Occupancy (AVO) is calculated as a weighted average, using the AVO for personal vehicles from USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020), AVO for trucks (assumed to be equal to 1.00), and the percentage of trucks. The Cal-B/C Corridor tool calculates the annual VHT by multiplying the daily (peak-period) VHT by the annualization factor (260). Then the value of time (different for personal and

[7] Sources: MoDOT Central Office – Highway Safety and Traffic Division and Missouri Traffic Safety Compendium, Missouri State Highway Patrol, Statistical Analysis Center.

commercial vehicles) is multiplied by the time spent in traffic to get the no-build and build travel time costs. The difference between the no-build and build costs is the travel time savings.

In the Preliminary Model, travel time benefits were calculated based on traffic volumes, speed, and project length, for the no-build and build scenarios. The percent truck traffic (based on project-specific data) was used to separate personal vehicle volumes from truck volumes in peak and non-peak periods. Similar to the Revised Model, the AVO values included in the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (January 2020) were used. The model multiplied the number of hours saved by personal and commercial vehicle drivers by their corresponding AVO values and values of time. Travel time costs were compared between the no-build and build scenarios and the difference was 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). The fuel and non-fuel costs are compared between the no-build and build scenarios, and the difference is the vehicle operating cost savings. This methodology is largely very similar in the Cal-B/C Sketch tool (Preliminary Model) and Cal-B/C Corridor tool (Revised Model).

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). This methodology is largely very similar in the Cal-B/C Sketch tool (Preliminary Model) and Cal-B/C Corridor (Revised Model) tool.

Operation & Maintenance Cost Savings (Disbenefit)

In the Revised Model, Operation & Maintenance (O&M) cost savings are calculated using an annual cost per lane-mile for O&M on the I-49 mainline, provided by MoDOT Department of Transportation staff. This annual O&M rate is applied to the increase in lane-miles from the project and across the full-period of analysis in the build scenario. From project open in the year 2024 to the end point of analysis in 2043, the change in operation and maintenance costs from the I-49 project amounts to $98,786 in discounted 2018 dollars. The Preliminary Model did not monetize this (dis)benefit.

7.2 Assumptions

The data and assumptions used in the estimation of economic benefits for the project are summarized in Table 6 to 11.

Error! Reference source not found. summarizes the crash data provided by the Safety Analysis for the I-49 Project (Appendix E of the application). Event per crash rates derived from Missouri statewide crash statistics and the monetization factors used to estimate safety benefits are summarized in Table 7.

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

Severity	Number of Accidents, 2023		Number of Accidents, 2045	
	No-Build	Build	No-Build	Build
Fatal	0.7	0.3	1.0	0.4
Disabling Injury	2.2	1.2	3.1	1.6
Minor Injury	11.5	11.0	16.9	15.1
PDO	56.2	34.6	80.7	48.4
Total	70.5	47.1	101.7	65.5

Table 7: Assumptions Used in the Estimation of Safety Benefits

Variable Name	Unit	Value	Source
Average Number of Fatalities per Fatal Crash	fatalities per crash	1.09	MoDOT Central Office – Highway Safety and Traffic Division and Missouri Traffic Safety Compendium, Missouri State Highway Patrol, Statistical Analysis Center.
Average Number of Injuries per Fatal Crash	injuries per crash	0.78	
Average Number of Vehicles per Fatal Crash	vehicles per crash	1.09	
Average Number of Injuries per Injury Crash	injuries per crash	1.43	
Average Number of Vehicles per Injury Crash	vehicles per crash	0.78	
Average Number of Vehicles per PDO Crash	vehicles per crash	1.43	
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	$3,2004,400	

The assumptions used in the estimation of travel time savings are summarized in Table 8.

Table 8: Assumptions Used in the Estimation of Travel Time Savings

Variable Name	Unit	Value	Source
Personal Vehicle Value of Time	dollars per hour	$16.60	USDOT, *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*, January 2020.
Commercial Vehicle Value of Time	dollars per hour	$29.50	
Personal Vehicle Average Vehicle Occupancy	persons per vehicle	1.48	
Commercial Vehicle Occupancy	Persons per vehicle	1.00	Conservative assumption.
Average Truck Percentage of Traffic	percentage	6.9%	Simple average from Traffic Analysis. This value varies among the modeling groups and ranges from 4.3% to 10.3%.
Annualization Factor for Vehicle Trips	days per year	260	Number of weekdays in a year.

The assumptions used in the estimation of vehicle operating cost savings are summarized in Table 9.

Table 9: 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	
Average Truck Percentage of Traffic	percentage	6.9%	Simple average from Traffic Analysis. This value varies among the modeling groups and ranges from 4.3% to 10.3%.
Annualization Factor for Vehicle Trips	days per year	260	Number of weekdays in a year.

The assumptions used in the estimation of emissions benefits are summarized in Table 10.

Table 10: 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	

The assumptions used in the estimation of Operations & Maintenance Cost Savings are presented in Table 11.

Table 11: Assumptions Used in the Estimation of Operations & Maintenance Cost Savings

Variable Name	Unit	Value	Source
Project Length	miles	5.94	Project information
No-build scenario lanes	lanes	4	
Build scenario lanes	lanes	6	
O&M cost	Dollars per lane-mile (per year)	$1,100	Missouri Department of Transportation correspondence

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 (23 years) and discounted at 7 percent to 2018 dollars. As stated earlier, construction is expected to be completed by the end of 2023. Benefits accrue during the full operation of the project.

Table 12: Overall Results of the Benefit Cost Analysis, Millions of 2018 Dollars*

Project Evaluation Metrics	Preliminary Results 7% Discount Rate	Revised Results 7% Discount Rate
Total Discounted Benefits	$61.3	$89.2
Total Discounted Costs	$31.0	$24.0
Net Present Value	$30.2	$65.2
Benefit / Cost Ratio	1.97	3.72
Internal Rate of Return (%)	16.5%	26.0%
Payback Period (years)	6 years	4 years

*Unless specified otherwise.

The Revised Model's travel time savings over full period ($56.5M) is greater than Preliminary Model's ($15.4M). The Revised Model's travel time savings is the primary factor behind its higher overall B/C ratio. The increase in time savings is due to the improved traffic and speed data for current and future years from the detailed Traffic Analysis for the project, which wasn't available for the preliminary analysis. Travel time benefits are also modeled at the roadway segment level for each peak period, which allows for increased detail in the analysis.

Table 13: Benefit Estimates by Category for the Build Scenario, Millions of 2018 Dollars

Benefit Categories	Preliminary Model		Revised Model	
	In Constant Dollars	7% Discount Rate	In Constant Dollars	7% Discount Rate
Accident Cost Savings	$102.5	$49.5	$115.6	$41.6
Travel Time Savings	$32.3	$15.4	$170.4	$56.5
Vehicle Operating Cost Savings	($7.6)	($3.7)	($26.6)	($8.5)
Emissions Cost Savings	($0.1)	($0.1)	($0.8)	($0.3)
Operation & Maintenance Cost Savings	Non-monetized	Non-monetized	($0.3)	($0.1)
Total Benefit Estimates	**$127.1**	**$61.3**	**$258.3**	**$89.2**

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 project team did not perform a sensitivity analysis in the Revised Model. Based on the results of the sensitivity analysis in the Preliminary Model (which largely resulted in BCA ratios above 1.0), and due to the data improvements made in the Revised Model, the project team is fairly confident in the revised BCA results.

The outcomes of the quantitative sensitivity analysis of the Preliminary Model for the I-49 Gateway to Kansas City Project are summarized in Table 14. 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 rows), as indicated in the column headers.

Table 14: 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.[8]	$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

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