Appendix C:

Benefit-Cost Analysis

Benefit-Cost Analysis Supplementary Documentation

INFRA Grant Program

Rocheport Bridge & Major I-70 Corridor Improvements

Missouri Department of Transportation

March 4, 2019

The Missouri Department of Transportation (MoDOT) is pursuing an Infrastructure For Rebuilding America (INFRA) grant for the **Rocheport Bridge & Major I-70 Corridor Improvements** project. The project entails construction of a new Missouri River Bridge at Rocheport (the Rocheport Bridge): 2) east-west truck climbing lanes at Mineola Hill; and 3) Transportation Systems Management and Operations (TSMO) strategies.

The Rocheport Bridge, climbing lanes at Mineola Hill, and TSMO strategies were assessed through three separate Benefit-Cost Analysis (BCA) models. The document outlines the assumptions, inputs and methodology used in all three analyses.

The table below outlines the BCA results for each project component and the overall BCA results for the **Rocheport Bridge & Major I-70 Corridor Improvements** project:

Rocheport Bridge & Major I-70 Freight Improvements Project BCA Summary

Benefit Cost Summary

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Vehicle Operating Costs	$1,888.5	$676.0	$4,333.9
Business Time and Reliability Costs	$4,086.6	$1,597.9	$8,817.4
Value of Personal Time and Reliability	$4,605.3	$1,699.0	$10,286.1
Safety	$839.4	$301.8	$1,923.6
Environmental: Non-CO2	$178.3	$65.5	$402.9
Logistics/Freight Costs	$414.5	$160.8	$903.9
Total Benefits	**$12,012.6**	**$4,500.9**	**$26,667.8**
Costs	**3% discount rate (in $millions)**	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Capital Investment Costs	$411.8	$343.8	$474.0
Operation and Maintenance Costs	$3.5	$1.5	$7.6
Total Costs	**$415.3**	**$345.3**	**$481.6**
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Net Present Value	$11,597.3	$4,155.6	$26,186.2
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Benefit/Cost Ratio	**29.17**	**13.09**	**56.25**

Benefit Cost Summary	I-70 Rocheport Bridge Replacement	I-70 Truck Climbing Lanes near Mineola Hill	I-70 Incident Management
Benefit	**7% discount rate (in $millions)**	**7% discount rate (in $millions)**	**7% discount rate (in $millions)**
Vehicle Operating Costs	$338.00	$0.00	$0.00
Business Time and Reliability Costs	$796.70	$6.00	$4.50
Value of Personal Time and Reliability	$847.40	$7.00	$4.10
Safety	$142.30	$2.40	$17.20
Environmental: Non-CO2	$32.70	$0.10	$0.00
Logistics/Freight Costs	$78.70	$5.00	$3.30
Total Benefits	**$2,235.80**	**$20.50**	**$29.20**
Costs	**7% discount rate (in $millions)**	**7% discount rate (in $millions)**	**7% discount rate (in $millions)**
Capital Investment Costs	$158.40	$3.80	$26.90
Operation and Maintenance Costs	($0.20)	$0.10	$1.90
Total Costs	**$158.20**	**$4.00**	**$28.80**
	7% discount rate (in $millions)	**7% discount rate (in $millions)**	**7% discount rate (in $millions)**
Net Present Value	**$2,077.60**	**$16.60**	**$0.40**
	7% discount rate	**7% discount rate**	**7% discount rate**
Benefit/Cost Ratio	**14.11**	**5.35**	**1.02**

Supplementary Documentation
A: Benefit-Cost Analysis Sources and Approach
B: Benefit Cost Analysis and Guide to Workbooks

Prepared for:
Missouri DOT
2019 INFRA Grant Application

Prepared by:

Metro Analytics

March 3, 2019

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SUPPLEMENTARY DOCUMENTATION A: TECHNICAL DOCUMENTATION OF BCA SOURCES AND METHODS

The Benefit Cost Analysis conducted for the projects in this INFRA Grant application depend on assumptions and valuation factors derived from the U.S. DOT Guidance as well as from other sources including the Missouri Department of Transportation for the projects. This supplementary documentation provides technical documentation of the key input assumptions and valuation factors used in the benefit-cost analysis and the Microsoft Excel modeling of travel, emissions and safety and shipper logistics benefits for each project included in this INFRA grant application package. Data sources are documented in footnotes. Conversions to 2017 dollars are made using the Bureau of Labor Statistics CPI Inflation Calculator.[1] (The benefit cost analysis results for each project are presented in subsequent Supplementary Documentation B.)

Value of Time

The per-person-hour values of time used for the analysis are those defined by the *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. Benefit estimation also adopts the Guidance-suggested car trip purpose splits for intercity travel by conventional surface modes[2]. Freight time costs were also taken from the same source. [3]

Table A-1 Value of Time by Mode and Purpose

Mode/Purpose	Value (2017 $ per person-hour)[4]
Truck – All	$28.60
Car – Business	$26.50
Car – Personal	$14.80

Table A-2 Car Trip Purpose Split

Trip Purpose	Percentage[5]
Car – Business	21.4%
Car – Personal	78.6%

[1] Accessible at: http://www.bls.gov/data/inflation_calculator.htm

[2] *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis* https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic

[3] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 29.

[4] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 29.

[5] The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2, Page 10.

Vehicle Occupancy

Vehicle occupancy rates are estimated from separate factors for trucks and cars. For trucks, crew per truck and freight tons per truck are used in the estimation. Passenger vehicle load factors come from the BCA Guidance.

Table A- 3 Crew, Passenger, and Freight Vehicle Loading Factors

Mode/Purpose	Crew Per Vehicle	Passenger per Vehicle[6]	US Freight Tons Per Vehicle[7]
Truck – All	1.0[8]	0	24.05
Car – Business	0	1.68	0
Car – Personal	0	1.68	0

Vehicle Operating Costs

Vehicle Operating Costs (VOC) are estimated using mileage-based costs (maintenance, tires, and mileage-based depreciation and insurance) that are separated from fuel-related costs (adjusted for differences in fuel consumption under congested and uncongested travel conditions) instead of one fixed per-mile Vehicle Operating Cost. This decoupling enables a more accurate estimate of VOC and when compared to combined fixed per-mile operating cost values is a more conservative approach.

The Vehicle Operating Cost (VOC) in dollars-per-mile includes the average per-mile cost of vehicles' tires, maintenance, and depreciation for travel in free-flow and congested conditions. (Fuel costs are treated separately, below). In order to derive costs per mile without fuel, the per mile fuel costs (see Table A-5) was subtracted from the $.39 per mile cited in the BCA Guidance (which includes operations and fuel), For passenger cars, for either business or personal use these amount to $.34 per mile. The passenger car per-mile VOC includes maintenance, tires, and mileage-based depreciation and insurance costs. Fixed costs of ownership related to depreciation, insurance, financing and licensing are removed from VOC. The truck per-mile VOC includes the costs of truck and trailer leases and purchase payments, repair and maintenance, insurance, permits and licenses, and tires. Costs for labor, fuel and truck tolls are included separately and amount to $.74 per mile.

Table A- 4 Per-Mile Vehicle Operating Costs Except Fuel

Mode/Purpose	Value (2017 $ per mile)[9]
Car – Personal	$0.39
Car – Business	$0.39

[6] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 30.

[7] 2002 Vehicle Travel Information System (VTRIS) average estimates of truck share and mean gross vehicle weight for straight trucks and tractor + single trailer trucks nationally, as summarized in FAF2 Freight Traffic Analysis. Chapter 3: Development of Truck Payload Equivalency Factors. Table 3.1: Results of Vehicle Weight Validation. http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/reports7/c3_payload.htm

[8] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 30.

[9] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 30.

Truck – All	$0.90

The fuel cost factors for Vehicle Gallons Per Mile (estimated gallons of fuel consumed per vehicle mile travelled) are from the FHWA Highway Statistics Series, in Table MV-1. The rates are calculated separately for free flow and congested conditions, with a fuel consumption penalty applied under congested conditions.[10] For passenger cars, under free flow conditions, consumption is .045 gallons per mile. Under congested conditions, consumption is .052 gallons per mile for cars, with a 15% fuel consumption penalty applied. For trucks, under free flow conditions, consumption is .156 gallons per mile. Under congested conditions, consumption is .218 gallons per mile, with a 40% fuel consumption penalty applied. The 2019 fuel costs per gallon are averages from the U.S. Department of Energy and are $3.01 per gallon of diesel and $2.32 for motor gasoline.[11]

Table A- 5 Per-Mile Vehicle Operating Costs – Gallons of Fuel Consumed

Mode	Trip Purpose	Average Gallons of Fuel Consumed		
		Per Mile (FF)[12]	Per Mile (Cong.)[13]	Per hour (Cong. or Idle)
Passenger Car	Business	0.0454	0.0522	0.0522
Passenger Car	Personal	0.0454	0.0522	0.0522
All Trucks	Freight	0.1559	0.2183	0.2183

Safety Costs

Mo DOT collects crash data on fatalities, injuries, and property damage. BCA Guidance recommends monetizing the value of injuries according to the Maximum Abbreviated Injury Scale (MAIS). The KABCO level values shown result from multiplying the KABCO-level accident's associated MAIS-level probabilities by the recommended unit Value of Injuries given in the MAIS level table, and then summing the products. The conversion is presented in Table A-6. The resulting costs are presented in Table A-7.

Table A- 6 Mapping of Mo DOT Accident Classification to BCA Guidance Classification

Mo DOT Crash Classification	INFRA Guidance Classification
Fatality	MAIS Fatal
Personal Injury	KABCO Injured (Severity Unknown)
Property Damage	KABCO No Injury

[10] Source: Zhang, K., S. Batterman, and F. Dion. 2011. Vehicle Emissions in Congestion: Comparison of work zone, rush hour, and free-flow conditions. Atmospheric Environment 45, pages 1929-1939.

[11] Taken from the US Department of Energy website on 2/20/2019. https://www.eia.gov/petroleum/gasdiesel/

[12] Source: Table MV-1 of the 2016 FHWA Highway Statistics Series

[13] Source: Table MV-1 of the 2016 FHWA Highway Statistics Series, with a fuel consumption penalty applied due to congested conditions of 15% for cars and 40% for trucks.

Table A- 7 Crash Valuation Factors

Value	$ per Fatalities Accident[14]	$ Per Personal Injury Accident	$ Per Property Damage Accident[15]
2017 $	$9,600,000	$174,000[16]	$4,300

Environmental Costs

Emissions generated on a per mile basis were calculated, using information from the U.S. EPA Office of Transportation and Air Quality. Emissions are valued according to TIGER and INFRA Grant Guidance, with a conversion factor from long tons to metric tons of: (2,240 lbs./2,205 lbs.) = 1.01587 metric tons per long ton.

Table A-7 Emissions Generated on a Per Mile Basis[17]

	Long tons per VMT				
Mode	**VOCs**	**NOx**	**Sox**	**PM**	**CO2**
Passenger Car	1.05E-06	7.04E-07	0.00E+00	4.32E-09	3.74E-04
All Trucks	1.18E-06	2.47E-06	1.79E-09	4.37E-08	9.63E-04

Table A- 8 Value per Metric Ton of Criteria Pollutant Emissions

Value per metric ton[18]	VOCs	NOx	SOx	PM
2017 $	$2,000	$8,300	$48,900	$377,800

[14] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 28.
[15] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 28.
[16] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 28.
[17] Values derived using multiple sources: EPA. Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks, October 2008, http://www.epa.gov/otaq/consumer/420f08024.pdf; Average In-Use Emissions from Heavy-Duty Trucks, October 2008, http://www.epa.gov/otaq/consumer/420f08027.pdf; Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008, http://epa.gov/climatechange/emissions/usinventoryreport.html; MOVES2010 model, March 2010 Build, Database MOVES20091221, in Hours of Service (HOS) Environmental Assessment, 2011, Appendix A, Exhibit A-4, "Long-haul and Drayage Truck Travel Emission Factors," http://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/2011_HOS_Final_Rule_EA_Appendices.pdf; "Policy Discussion – Heavy-Duty Truck Fuel Economy," Presentation by Drew Kodjak, National Commission on Energy Policy, 10th Diesel Engine Emissions Reduction (DEER) Conference, August 29 – September 2, 2004, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/deer_2004/session6/2004_deer_kodjak.pdf.
[18] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Page 31.

Shipper Logistics Costs

Shipper logistics costs are the value of freight quantifying the value of time for reliability in deliveries which are part of just-in-time and lean logistics supply chain inventory management. Standard operating procedures for many industries such as high-value manufacturers including maintaining reduced safety stocks, which lowers the opportunity cost of capital. The calculation of the shipper logistics cost category requires a profile of the types of commodities that are being shipped within, to, and from the study area and cannot readily be calculated within a spreadsheet but is adapted from a methodology used and documented in Missouri DOT's 2017 INFRA application for the same projects.

Project-Specific Assumptions

I-70 Rocheport Bridge Replacement Assumptions

The Rocheport bridge on I-70 is approaching the end of its useful life. It needs to be either replaced right away, or undergo a major renewal to help keep it in service another ten-years, at which point it will likely no longer be safe for use by trucks, and within five years thereafter will not be safe for use by passenger cars either. Lost use of the Rocheport bridge would impose significant costs on the US Economy as I-70 would no longer be a continuous trans-continental route, and there would be significant diversion costs as documented in the supplemental report: *Rocheport Bridge Posting and Closure Analysis*. A full accounting of costs associated with loss of the Rocheport bridge due to lack of funding is beyond what can be quantified in the current application. Consequently, the BCA methodology here focuses primarily on the minimum potential long-term costs associated with passenger and care diversion imposed by failure to replace the Rocheport bridge.

The analysis does not quantify additional unknown costs such as the safety implications of diverting trucks and long-distance car traffic from interstate to non-interstate facilities (with commensurate changes in average crash rates), the environmental implications of diverting traffic from a fully controlled highway to routes characterized by intersection stops and the costs of decommissioning and de-constructing the Rocheport bridge to ensure safe navigation on the Missouri River. Furthermore, the localized air quality and noise costs associated with passing even a share of Rocheport's traffic through local communities on the NHS are not quantified here as such would require a major study beyond the resources, timing or complexity of the current application. Hence in effect, the user benefits of preserving the Rocheport bridge are presented as a minimum. Furthermore, based on feedback received from Missouri DOT's 2017 INFRA application, the current application does not presume an eventual, but later replacement in the base-case condition – as the funds for such a replacement are not identified and no such replacement is programmed at this time.

To analyze this situation, the minimum costs imposed by loss of the Rocheport bridge are shown in the base-case to begin in 2030; eight years after a $16 Million rehabilitation; when Mo DOT engineering estimates indicate a likely closure to trucks would be needed. Five years later (by 2035, approximately 12 years after completion of a 2023 rehabilitation, it is assumed that the bridge would close to all traffic and impose diversion costs on both cars and trucks without the replacement requested in the current grant application. Furthermore, it is assumed that the annual operation and maintenance costs will be higher during the period following the rehabilitation leading up to posting and closure in the base case than they would be under the replacement build scenario enabled by the INFRA grant on account of the replacement providing a new starting bridge condition. While many of the ancillary facilities that have been used as short-term detour routes are not today capable of accommodating permanent re-assignment from loss of the Rocheport bridge, the analysis conservatively assumes that in the period leading up to the posting and closure, these facilities may be prepared for this function. Consequently instead of assuming diversion as would have to occur on today's national network (as represented in the ITTS SHIFT model described in the supplemental report (*Rocheport Bridge Posting and Closure Analysis)* the analysis assumes that routes that have been used in the past as short-term diversion routes would ultimately be available, enabling the benefit of Rocheport's preservation to be less than might be the case if conditions shown in the ITTS network alone prevail. Consequently, Mo DOT's . Mo DOT's data for the last three years of lane closures and their duration for bridge maintenance together with a spatial analysis of available Missouri river crossings and alternative routes is presented in the supplemental report and underlies this scenario. In every case lane were reduced from 2/direction to 1/direction. Delays under such conditions can be substantial and would cause many local trips who are aware of the delays to reroute, and even some national interstate trips would reroute.

I-70 Truck Climbing Lanes near Mineola Hill Assumptions

Mo DOT is proposing to improve I-70 with the addition of truck climbing lanes to reduce congestion caused by steep grades near the town of Mineola.

The approach to comparing the base versus build conditions for these projects included consideration of current traffic and forecasted growth in traffic. For each proposed widening, the number of trips affected was 1-hour of volume per day, conservatively ignoring any additional delay that may occur. Affected 1-hr volume was increased at 1% per year to the final 2057 analysis year. In actuality, as volume grows at 1%, it is likely the more than 1% would be affected, because congestion would spill over to more than 1-hour per day, thereby affecting more of the daily volume. However, this time spill-over was conservatively excluded in this analysis.

Both trips and VMT were held constant in both base and build, implying there would be no diversion of traffic due to recurring delays. However, VHT is affected, with 1-hr slowdowns in the base averaging 45 mph throughout the 40-yr analysis period and returning to 70 mph for all 40-yrs after each project is completed. As traffic grows at 1%, speeds would not remain a constant 45 mph. But for convenience it was assumed that 45 mph might be a representative average throughout the years.

Truck speeds were assumed to average 37 mph throughout the 40-yr period without the project and could be restored to 45 mph by the project. This is to recognize that trucks will not travel much faster than this uphill anyway, but that without the project they would be even slower as they'd be impacted by congestion as well as grade. However, passenger vehicle speeds would average 45 uphill without the project (same as other widenings) and could be restored to average 65 mph uphill with the project.

With these elements, it is possible to compute project benefits with resulting total trips, VMT, and VHT affected annually in both the base and build scenarios for each improvement project with widening.

I-70 Incident Management System Assumptions

Because the Incident Management System (IMS) projects affect traffic and crashes along the I-70 , assumptions specific to the benefits of the IMS were necessary. We assumed the IMS projects will decrease the duration of incidents, increase diversion due to incidents, improve speeds during incidents, and reduce secondary crashes. New CCTV locations and Portable Communication Pads are expected to allow incidents to be detected and reported more quickly, and new median crossovers can help emergency vehicles reach and clear incidents faster. A reduction of **20% in incident durations** was assumed on **I-70**. For reference, an analysis of the effectiveness of CHART, Maryland's incident management program, saw a reduction in incident duration of 23%[19]. Current incident durations and frequency of incidents, at the segment level, were inferred based on 5 years of HERE speed data. The reduction in incident duration results in a commensurate reduction in the fraction of VMT that experiences congestion.

The incident management system project also includes the construction of new or improved outer roads and new slip ramps. These improvements reduce the diversion distance traveled by vehicles that divert during incidents. For segments with new or improved outer roads, the improved diversion distance was assumed to be 1.2 times the distance along the highway, if this distance is less than the current distance. We also assumed that due to these improvements and to additional DMS boards that can inform drivers of incidents, larger shares of traffic will divert during incidents. The share of truck traffic that is expected to divert was assumed to increase from 8-15%, depending on outer road capacity, to 9-18%. Passenger cars were expected to fill the remaining outer road capacity during incidents. The percent of passenger cars that divert was capped at 40% prior to the incident management system, and at 55% after.

We also assumed that if quicker detection and improved communication regarding incidents allows vehicles to divert sooner, early-diverting vehicles will experience faster speeds on diversion routes. On average it is assumed that speeds on diversion paths would increase from 32 mph to 39 mph. Increased diversion is also assumed to result in higher speeds on the highway during incidents. Based on analysis of five years of HERE speed data for I-70, the average highway speed during an incident is 28 mph. We assumed that the share of vehicles during incidents that experience very low speeds will decrease, bringing the average speed up to 35 mph.

Crash data from rural I-70 documents that 6% of crashes are secondary. This may be a conservative estimate, as some secondary crashes may not be reported in the database or may not have been recorded as secondary crashes by responding officers. An analysis of I-66 in Virginia found that 9.2% of crashes were secondary[20], while the National Traffic Incident Management Coalition states that 20% of crashes are secondary. Secondary crashes due to congestion resulting from a previous crash are estimated to represent 20 percent of all crashes.[21] We assumed that 6% of crashes are secondary.

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[19] http://ntimc.transportation.org/Documents/Benefits11-07-06.pdf

[20] http://people.virginia.edu/~njg2q/secondary.pdf

[21] http://ntimc.transportation.org/Documents/Benefits11-07-06.pdf

A study in Indiana found that for each minute of incident duration, the likelihood of a secondary crash increased by a factor of 1.028. Based on that study, we assumed that the likelihood that a primary crash is associated with a secondary crash will be reduced by a factor of 1.161 on I-70 due to the reductions in incident durations or 20 percent and 10 percent, respectively. Analysis of the severity of secondary crashes on I-70 shows higher rates of severe crashes (fatality and personal injury crashes) when compared to all crashes. This distribution was reflected in the reduction in crashes assumed.

SUPPLEMENTARY DOCUMENTATION B: BCA RESULTS BY PROJECT AND GUIDE TO BCA WORKBOOK CALCULATIONS

Benefit Cost Analysis Results Details

The benefit cost analysis (BCA) of the projects were conducted using the input assumptions described in Supplementary Documentation A and detailed in the accompanying live Microsoft Excel Workbooks titled “MoDOT BCA I-70 Incident Management_2019.xlsx” “MoDOT BCA I-70 Mineola_2019.xlsx” and “MoDOT BCA I-70 Rocheport Bridge_2019.xlsx.”

This Supplementary Documentation B contains the summary tables with the BCA results for each component project as well as the total for the combined application package of projects. Each of these is also included in the accompanying MS Excel BCA workbooks, documenting the results presented in the main body of the application. The project-specific BCA results summary tables follow the guide to the contents of the BCA Excel Workbooks presented next.

Benefit Cost Analysis Workbook Guide

Within the application’s benefit cost analysis Microsoft Excel workbooks are individual workbooks with the details of each component project’s BCA and the combined BCA for the INFRA grant application package of projects.

For each project workbook, the BCA inputs and results are presented across multiple worksheets in table formats that document the results, the calculations and the inputs and assumptions. There are separate worksheet tabs for each project and the combined total with the overall BCA, the benefits summary, the project costs, the travel demand characteristics (TDC), the benefit calculations, the fixed factor inputs, the cost summary discounted, and the crash reductions.
For each project BCA workbook, the BCA Summary tabs present the calculated benefit cost ratio for the project under net present value calculations using the 3% and 7% discount rates for the benefit and cost categories derived from the supporting tables in the other tabs.

The Benefits Summary tabs include in one tab the undiscounted and discounted at 3% and 7% benefits streams for the project year-by-year. The separately-derived benefits categories are detailed in columns for Vehicle Operating Costs; Business Time & Reliability Costs; Value of Personal Time & Reliability; Safety Cost; Environmental Cost; Shipper/ Logistics Cost; and a Total for the benefits categories.

The Project Costs tabs contain the year-by-year no-build baseline and the with-project build alternative undiscounted costs for each cost category and total: Property Acquisition Engineering and Design; Right of Way; Transport Structures; Terminal; Vehicles; Total Capital; Ongoing Operations; Maintenance and Rehabilitation; and, Total Operations and Maintenance.

The Travel Demand Characteristics (TDC) tabs include the travel demand modeling results comparing the base no-build and the with-project scenarios interpolated year-by-year. The trips, the vehicle miles traveled, the percent congested, the vehicle hours traveled, and the buffer time are detailed for personal and business use of passenger cars and for freight trucks. The crashes are estimated for fatalities, personal injuries and property damage.

The Benefit Calculations tabs include the year-by-year values comparing the baseline no-build alternative to the with-project alternative for Vehicle Operating Cost; Value of Time; Reliability; Safety; and Non-CO2 Emissions. These benefit streams are detailed for personal and business use of passenger cars and for freight trucks.

The Fixed Factors tabs present the input assumptions used for vehicle operations and for emissions by business and personal use of passenger cars and for freight trucks.
The Cost Summary Discounted tabs summarize the start-up costs and the ongoing operations and maintenance costs year-by-year with the discounting at 3% and the 7% alternative discount rates with the full-period totals at the end.

The tabs for Crash Reductions, compare the no-build alternative to the project alternative costs of property damage, personal injury and fatal accidents discounted at 7% and 3% across the evaluation period from 2020 to 2053. The costs are separately calculated for freight trucks as well as personal and business use of passenger cars. The crash rates are from the Bureau of Transportation Statistics (BTS) National Transportation Statistics (NTS) Tables. Car and truck crash rates are from NTS Chapter 2 Section C.

Benefit Cost Analysis Results Project Summaries

The summary of the total benefits and costs of the package of projects in this INFRA Grant application follows. The subsequent tables present the summaries of the BCA for each individual project.

Rocheport Bridge & Major I-70 Freight Improvements Project BCA Summary

Benefit Cost Summary

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
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Net Present Value	$11,597.3	$4,155.6	$26,186.2
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Benefit/Cost Ratio	**29.17**	**13.09**	**56.25**

I-70 Rocheport Bridge Replacement BCA Summary

I-70 Rocheport Bridge Replacement Benefit Cost Summary

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Vehicle Operating Costs	$944.2	$338.0	$2,166.9
Business Time and Reliability Costs	$2,038.7	$796.7	$4,400.1
Value of Personal Time and Reliability	$2,298.4	$847.4	$5,135.1
Safety	$402.2	$142.3	$929.1
Environmental: Non-CO_2	$89.1	$32.7	$201.4
Logistics/Freight Costs	$203.9	$78.7	$445.7
Total Benefits	**$5,976.5**	**$2,235.8**	**$13,278.3**

Costs	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Capital Investment Costs	$189.9	$158.4	$218.7
Operation and Maintenance Costs	-$0.2	-$0.2	-$0.3
Total Costs	**$189.6**	**$158.2**	**$218.4**

	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Net Present Value	$5,786.9	$2,077.6	$13,059.9

	3% discount rate	7% discount rate	Undiscounted (in $millions)
Benefit/Cost Ratio	**31.48**	**14.11**	**60.72**

I-70 Truck Climbing Lanes near Mineola Hill BCA Summary

I-70 Truck Climbing Lanes near Mineola Hill Benefit Cost Summary

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Vehicle Operating Costs	$0.0	$0.0	$0.0
Business Time and Reliability Costs	$11.1	$6.0	$19.5
Value of Personal Time and Reliability	$12.7	$7.0	$22.3
Safety	$4.4	$2.4	$7.8
Environmental: Non-CO_2	$0.1	$0.1	$0.2
Logistics/Freight Costs	$9.4	$5.0	$16.7
Total Benefits	**$37.8**	**$20.5**	**$66.6**

Costs	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Capital Investment Costs	$4.4	$3.8	$5.0
Operation and Maintenance Costs	$0.4	$0.1	$0.6
Total Costs	**$4.8**	**$4.0**	**$5.6**

	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Net Present Value	$33.0	$16.6	$60.9

	3% discount rate	7% discount rate	Undiscounted (in $millions)
Benefit/Cost Ratio	**8.43**	**5.35**	**13.19**

I-70 Incident Management Project BCA Summary

I-70 Incident Management Project Benefit Cost Summary

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Vehicle Operating Costs	$0.0	$0.0	$0.1
Business Time and Reliability Costs	$9.2	$4.5	$17.1
Value of Personal Time and Reliability	$8.5	$4.1	$15.9
Safety	$35.0	$17.2	$65.4
Environmental: Non-CO_2	$0.1	$0.0	$0.2
Logistics/Freight Costs	$6.7	$3.3	$12.5
Total Benefits	**$59.6**	**$29.2**	**$111.2**

Costs	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Capital Investment Costs	$32.0	$26.9	$36.6
Operation and Maintenance Costs	$4.0	$1.9	$8.2
Total Costs	**$36.0**	**$28.8**	**$44.8**

	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Net Present Value	$23.5	$0.4	$66.4

	3% discount rate	7% discount rate	Undiscounted (in $millions)
Benefit/Cost Ratio	**1.74**	**1.02**	**2.81**

ROCHEPORT BRIDGE POSTING AND CLOSURE ANALYSIS

The Rocheport bridge is at the end of its useful life. If it is not replaced right away, MoDOT will be compelled to spend significantly within a year or two in order to squeeze another 10-years of useful life from the bridge. At that point, somewhere around 2030, the bridge can no longer be rehabilitated for continued safe passage, and will need to be closed to truck traffic. It is expected the bridge could safely serve lighter weight passenger vehicles until about 2035, at which point it would be closed entirely due to safety concerns.

To test this scenario, two methods were used. The first method is based on a national TransCAD travel demand model, known as the SHIFT model, which was obtained from the Institute for Trade and Transportation Studies (ITTS). The model was run with and without the Rocheport bridge for a base year and horizon year.

When the bridge is gone, both passenger and truck traffic will be forced to divert to their next best options. For transcontinental freight, alternative path decisions will be made states away, and the TransCAD model shows significant rerouting to I-80 to the north, and I-40/I-44 to the south. For more localized trips, there are closer bridges that passenger traffic would use, but these bridges and the roadways serving them are not capable of supporting high levels of sustained truck traffic, so the TransCAD modeling assumed that trucks would be required to divert to roadways and bridges that could sustain them for years on end.

In addition to the added VMT, TransCAD predicts that the hours of delay for both passenger vehicles and trucks would skyrocket. This is partly because the added traffic to parallel interstates (I-80 and I-40/I-44), would increase congestion on those routes through urban areas. But the main source of additional delay comes from at-grade rural arterial highways all within Missouri that are often impeded by stop signs and traffic signals in small towns. These routes would simply get massively congested if forced to handle traffic diverted from I-70, and pavements would also degrade quickly.

Below is the number of Passenger and Truck trips and associated VMT and VHT as per the TransCAD model.

Annual Summary	Pass Trip	Trk Trip	Pass VMT	Trk VMT	Pass VHT	Trk VHT
2016, No Bridge	8,700,000	2,400,000	2,301,970,000	1,534,650,000	35,720,000	23,810,000
2016, Yes Bridge	8,700,000	2,400,000	2,034,000,000	1,356,000,000	23,130,000	15,420,000
2040, No Bridge	11,400,000	3,000,000	3,082,920,000	2,055,280,000	70,020,000	46,680,000
2040, Yes Bridge	11,400,000	3,000,000	2,610,000,000	1,740,000,000	37,210,000	24,800,000

Assuming that the bridge were closed to all traffic in 2020 and remained closed until 2060, these VMT and VHT increases, when converted into a benefits stream, are shown in the following table. At a 7% discount rate, keeping the bridge open during those years is worth $18.8 billion in societal benefit, while the cost to replace it, and thereby keep it open, is $158 million (7% discounted). The resulting Benefit / Cost ratio is thereby a very impressive $119 benefit for every dollar spent.

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Vehicle Operating Costs	$9,159	$4,598	$17,183
Business Time and Reliability Costs	$13,752	$6,758	$26,242
Value of Personal Time and Reliability	$10,453	$5,064	$20,181
Safety	$3,471	$1,736	$6,534
Environmental: Non-CO_2	$1,080	$546	$2,016
Logistics/Freight Costs	$204	$79	$446
Total Benefits	**$38,120**	**$18,782**	**$72,603**
Costs	**3% discount rate (in $millions)**	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Capital Investment Costs	$189.9	$158.4	$218.7
Operation and Maintenance Costs	-$0.2	-$0.2	-$0.3
Total Costs	**$190**	**$158**	**$218**
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Net Present Value	$37,930	$18,623	$72,384
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Benefit/Cost Ratio	**201**	**119**	**332**

The reality of closing a federal interstate for 40 years would no double create huge economic losses, but at this scale it caused us to ask more probing questions. Missouri does believe that by spending around $16-million fairly soon, they can extend the bridge life by 10 years for trucks, and 15 for vehicles, so we ran a second BCA analysis assuming the closure could be delayed. Secondly, if I-70 did close and never reopened, Missouri would end up improving alternative rural highways to handle their local truck traffic at far less congested conditions. Additionally, the TransCAD model assumes VMT would increase as normal, but in reality the huge increase in travel time would cause many trips not to be made, or to adjust to more favorable times and modes.

Thus a second analysis was conducted which assumed transcontinental trips would not incur much additional VMT because when deciding in California how to get to Chicago, I-80 and I-40/44 are nearly the same as I-70 in terms of VMT. And while VHT would likely increase due to increased congestion, urbanized areas would adjust to the modest increase. Locally within Missouri, diverted VMT was calculated by assuming some of the traffic would divert to a bridge that crosses the Missouri River slightly north of Rocheport in a town called Boonville, and the rest would divert to a roadway that is more capable of higher volumes, but also further away, crossing the river at Jefferson City. The table below shows how the second method allocates annual VMT and VHT.

Annual Summary	Pass Trip	Trk Trip	Pass VMT	Trk VMT	Pass VHT	Trk VHT
2016, No Bridge	8,700,000	2,400,000	2,317,680,000	1,362,600,000	42,900,000	21,560,000
2016, Yes Bridge	8,700,000	2,400,000	2,070,600,000	1,302,000,000	29,580,000	18,600,000
2040, No Bridge	11,400,000	3,000,000	3,036,960,000	1,703,250,000	56,220,000	26,950,000
2040, Yes Bridge	11,400,000	3,000,000	2,713,200,000	1,627,500,000	38,760,000	23,250,000

Processing the VMT and VHT values of the second method through the same BCA spreadsheet as before yields about $6.0 Billion in benefits, where before was about $38 billion. This is largely because the benefit stream does not start until 2030 for trucks, and 2035 for passenger vehicles, but also because of assumptions that traffic would adjust over time, and Missouri's highways would also adapt to the additional traffic (though the cost of those upgrades was not accounted for in the BCA analysis). Thus the overall Benefit / Cost ratio at 7% discount is 14.11 in this case, where the TransCAD method predicted 119.

Benefit	3% discount rate (in $millions)	7% discount rate (in $millions)	Undiscounted (in $millions)
Vehicle Operating Costs	$944.2	$338.0	$2,166.9
Business Time and Reliability Costs	$2,038.7	$796.7	$4,400.1
Value of Personal Time and Reliability	$2,298.4	$847.4	$5,135.1
Safety	$402.2	$142.3	$929.1
Environmental: Non-CO_2	$89.1	$32.7	$201.4
Logistics/Freight Costs	$203.9	$78.7	$445.7
Total Benefits	**$5,976.5**	**$2,235.8**	**$13,278.3**
Costs	**3% discount rate (in $millions)**	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Capital Investment Costs	$189.9	$158.4	$218.7
Operation and Maintenance Costs	-$0.2	-$0.2	-$0.3
Total Costs	**$189.6**	**$158.2**	**$218.4**
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Net Present Value	$5,786.9	$2,077.6	$13,059.9
	3% discount rate (in $millions)	**7% discount rate (in $millions)**	**Undiscounted (in $millions)**
Benefit/Cost Ratio	**31.48**	**14.11**	**60.72**