Cost-Effectiveness Analysis Supplementary Documentation

FASTLANE Discretionary Grant Program

I-44/US75 Interchange Improvements in Tulsa County

Oklahoma Department of Transportation (ODOT)

April 14, 2016

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Cost Effectiveness Analysis Supplementary Documentation

1 Executive Summary

The Cost-Effectiveness Analysis conducted for this grant application compares the costs associated with the proposed investment to the benefits of the project. To the extent possible, benefits have been monetized. Where not possible to assign a dollar value to a benefit, efforts have been made to quantify it. A qualitative discussion is also provided when a benefit is anticipated to be generated but is not easily monetized or quantified.

I-44 in Tulsa, between I-244 and the Arkansas River, is currently a four-lane divided highway. This portion of I-44 is one of the oldest and earliest pieces of interstate in Oklahoma and has not been upgraded since it was constructed in the Eisenhower years. Due to increasing congestion levels and the state of repair of the related infrastructure, the Oklahoma Department of Transportation (ODOT) is looking to reconstruct approximately one mile of I-44, from the I-44/Union Avenue grade separation to the Arkansas River. The project will also widen I-44 from four through lanes to six through lanes and include spot improvements along this corridor to facilitate the ultimate configuration of the local 2.5mile stretch of I-44 which will eventually be completely reconstructed to meet the demands of growing intra- and interstate freight demands, address significant safety issues, and upgrade to current interstate standards.

The Project is anticipated to have substantial improvements which include the following:

- Significant travel time savings for private and commercial drivers along the corridor;
- Improve the movement of people along the corridor by reducing congestion;
- Achieve significant reduction in traffic fatalities and serious injuries by virtue of providing more miles of safer highway infrastructure; and
- Reduce emissions for pollutants such as carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_x), fine particulate matter (PM2.5), Sulfur Dioxide (SO_x) and Carbon Dioxide (CO_2).

A table summarizing the changes expected from the project, and the associated benefits, is provided below.

Table ES-1: Merit Criteria and Cost-Effectiveness - Summary of Infrastructure Improvements and Associated Benefits, Millions of 2015 Dollars

Current Status or Baseline & Problems to be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Population Affected by Impacts	Economic Benefit	Summary of Results ($M Discounted at 7%)	Page in BCA Report
Travel Delays for Passenger Vehicles and Trucks due to congestion on the I-44.	Increase the capacity of I-44 by widening I-44 from four through lanes to six through lanes along with other spot infrastructure improvements along the corridor.	Improved travel speeds, reduced long-term congestion, fuel savings	Passenger vehicles, trucks	Travel Time and Vehicle Operating Cost Savings	$316.27	Pg. 12
		Emission Savings	Passenger vehicles, trucks	Emissions Cost Reduction	$4.52	Pg. 14
		Improved Safety	Passenger vehicles, trucks	Accident Cost Reduction	$88.75	Pg. 15

The period of analysis used in the monetization of benefits and costs corresponds to 27 years, including 7 years of construction and 20 years of operation. The total undiscounted project capital costs[1] are $110.8 million dollars with an average $50 thousand in ongoing maintenance costs.

A summary of the relevant data and calculations used to derive the monetized benefits and costs of the project are shown in **Table ES-3** (in 2015 dollars). Based on the analysis presented in the rest of this document, the project is expected to generate $409.5 million in discounted benefits and $103.1 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value (NPV) of $306.5 million and a Benefit/Cost Ratio of 3.97.

Table ES-2: Summary of Pertinent Data, Quantifiable Benefits and Costs, Discounted at 7%

Calendar Year	Project Year	Economic	Safety	Community and Environmental	Total Benefits	Total Costs
2016	1	$0	$0	$0	$0	$664,685
2017	2	$0	$0	$0	$0	$1,725,178
2018	3	$0	$0	$0	$0	$1,403,790
2019	4	$0	$0	$0	$0	$34,953,917
2020	5	$0	$0	$0	$0	$32,320,872
2021	6	$0	$0	$0	$0	$22,597,607
2022	7	$0	$0	$0	$0	$8,979,277
2023 (opening)	8	$19,161,174	$6,986,747	$226,032	$26,373,953	$38,145
2024	9	$20,120,538	$6,638,039	$429,373	$27,187,950	$35,649
2025	10	$19,601,672	$6,306,470	$431,510	$26,339,653	$33,317

[1] Total project costs include capital costs and operation & maintenance (O&M) costs. Cost data was provided in 2015 Dollars. Annual monetized estimates of total project costs are presented in section 10.

Calendar Year	Project Year	Economic	Safety	Community and Environmental	Total Benefits	Total Costs
2026	11	$19,076,832	$5,991,213	$432,089	$25,500,135	$31,137
2027	12	$18,548,380	$5,691,483	$431,283	$24,671,146	$29,100
2028	13	$18,018,429	$5,406,528	$429,249	$23,854,206	$27,197
2029	14	$17,488,861	$5,135,635	$426,133	$23,050,629	$25,417
2030	15	$16,961,349	$4,878,122	$184,233	$22,023,704	$23,755
2031	16	$16,437,374	$4,633,341	$183,902	$21,254,617	$22,201
2032	17	$16,233,208	$4,400,673	$119,028	$20,752,909	$20,748
2033	18	$15,701,115	$4,179,530	$120,796	$20,001,440	$19,391
2034	19	$15,177,137	$3,969,350	$122,105	$19,268,592	$18,122
2035	20	$14,662,074	$3,769,600	$122,996	$18,554,669	$16,937
2036	21	$14,156,605	$3,579,771	$123,507	$17,859,883	$15,829
2037	22	$13,661,305	$3,399,378	$123,676	$17,184,358	$14,793
2038	23	$13,176,651	$3,227,959	$123,534	$16,528,144	$13,825
2039	24	$12,703,033	$3,065,077	$123,112	$15,891,222	$12,921
2040	25	$12,240,762	$2,102,317	$122,439	$14,465,519	$12,076
2041	26	$11,790,078	$2,763,265	$121,541	$14,674,884	$11,286
2042	27	$11,351,157	$2,623,559	$120,441	$14,095,157	$10,547
Total		**$316,267,734**	**$88,748,058**	**$4,516,979**	**$409,532,771**	**$103,077,718**

In addition to the monetized benefits presented in **Table ES-3**, the project would generate other benefits that are difficult to monetize as explained below.

Economic Outcomes

The higher speeds along the corridor provided by the project imply that trucks spend less time on the road and can reach their destinations faster. The delivery times will lead to inventory cost savings, which are important to improve connectivity between production and consumption sites and to increase the fluidity of the movement of goods. Inventory cost savings were not monetized as part of the BCA. US DOT is developing a methodology to estimate inventory cost savings but that methodology is not yet available.

Mobility Outcomes

A mobility benefit that was identified but not monetized as part of the BCA is travel time reliability. One trip reliability measure is the buffer index, which is simply the additional time required to make the trip compared with uncongested conditions. Given that crashes and incidents can add to these times, these “buffers” indicate a current high degree of future trip unreliability.

2 Introduction

This document provides detailed technical information on the economic analyses conducted in support of the Grant Application for the I-44/US75 Interchange Improvement Project in Tulsa County, Oklahoma.

Section 3, Methodological Framework, introduces the conceptual framework used in the Cost-Effectiveness Analysis. To the extent possible, and as recommended in the Notice of Funding Opportunity (NOFO), monetized benefits and costs are estimated through a Benefit-Cost Analysis (BCA), which is described in this section. Section 4, Project Overview, provides an overview of the project, including a brief description of existing conditions and proposed alternatives; a summary of cost estimates and schedule; and a description of the types of effects that the Project is expected to generate. Monetized, quantified, and qualitative effects are highlighted. 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 merit criteria are presented in Section 7, Benefits Measurement, Data and Assumptions, along with associated benefit estimates. Estimates of the project's Net Present Value (NPV), its Benefit/Cost ratio (BCR) and other project evaluation metrics are introduced in Section 8, Summary of Findings and BCA Outcomes. Next, Section 9, BCA Sensitivity Analysis, provides the outcomes of the sensitivity analysis. Additional data tables are provided in Section 10, Supplementary Data Tables, including annual estimates of benefits and costs, as well as intermediate values to assist DOT in its review of the application.

3 Methodological Framework

The Cost-Effectiveness Analysis conducted for this project includes the monetized benefits and costs measured through Benefit-Cost Analysis (BCA), as well as the quantitative and qualitative merits of the project. BCA is a conceptual framework that quantifies in monetary terms as many of the costs and benefits of a project as possible. Benefits are broadly defined. They represent the extent to which people impacted by the project are made better-off, as measured by their own willingness-to-pay. In other words, central to BCA is the idea that people are best able to judge what is "good" for them, what improves their well-being or welfare.

BCA also adopts the view that a net increase in welfare (as measured by the summation of individual welfare changes) is a good thing, even if some groups within society are made worse-off. A project or proposal would be rated positively if the benefits to some are large enough to compensate the losses of others.

Finally, BCA is typically a forward-looking exercise, seeking to anticipate the welfare impacts of a project or proposal over its entire life-cycle. Future welfare changes are weighted against today's changes through discounting, which is meant to reflect society's general preference for the present, as well as broader inter-generational concerns.

The specific methodology developed for this application was developed using the above BCA principles and is consistent with the FASTLANE guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the build and no-build scenarios
- Assessing benefits with respect to each of the four merit criteria identified in the FASTLANE BCA guidance;
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;
- Using DOT guidance for the valuation of travel time savings, safety benefits and reductions in air emissions, while relying on industry best practice for the valuation of other effects;
- Discounting future benefits and costs with the real discount rates recommended by the DOT (7 percent, and 3 percent for sensitivity analysis); and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

The BCA was primarily conducted using a modified corridor version[2] of the California Lifecycle Benefit/Cost Analysis Model (Cal-B/C v5.1 Corridor). 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 State Transportation Improvement Program (STIP) since 1996. As part of a 2009 Cal-B/C revision, Caltrans developed a suite of tools for conducting benefit-cost analysis. While the original model retains a sketch planning format, Cal-B/C Corridor supports BCA after user impacts are modeled in a planning or engineering tool.

Cal-B/C Corridor estimates benefits using changes in vehicle-miles traveled (VMT) and vehicle-hours traveled (VHT) from travel demand or micro-simulation models. The model has a flexible design that supports a variety of input data. Cal-B/C Corridor uses analysis methods consistent with the procedures outlined in the Federal Highway Administration's (FHWA's) *Economic Analysis Primer (2003).* The updated version of Cal-B/C corridor includes the ability to account for increases in the value of time, consistent with the latest Federal guidance.

For this FASTLANE Grant Application, the standard Cal-B/C Corridor assumptions and economic values were modified to adhere to the requirements stipulated by the US DOT. The resulting values are consistent with the guidance found in the supplemental TIGER and FASTLANE BCA Resource Guide (March 2016). Cal-B/C Corridor was run to monetize the costs and benefits estimated using the travel demand model results. Information pertaining to the travel demand model is provided in Section 6. Using Cal-B/C Corridor, the following three primary categories of user benefits were quantified for the Project: travel time savings, vehicle operating cost savings, and emission reductions, including greenhouse gases. Cal-B/C Corridor does not estimate safety benefits of the project directly. The monetized safety benefits were estimated externally in a separate spreadsheet. The resulting benefits were then inputted into the Final Calculations page of Cal-B/C Corridor to be included in the BCA.

[2] Cal-B/C Corridor estimates annual benefits over a standard 20-year lifecycle. For analyses purposes, this model was expanded in order to use a 30-year lifecycle as ALDOT expects the project to have a longer lifecycle.

4 Project Overview

The I-44/US75 Interchange Improvement Project in Tulsa County, Oklahoma, is located within the I-44 corridor, a portion of the Primary Highway Freight Network, from its intersection with I-244 extending east approximately two and one-half miles to the Arkansas River. The project is within the Tulsa urbanized area and the Tulsa Transportation Management Area.

4.1 Base Case and Alternatives

The no-build scenario (base case) as defined in this project is the status quo, or the existing infrastructure within I-44 Corridor. This scenario leaves gaps in the overall connectivity of the region due to the capacity constraints. The build scenario being considered includes the reconstruction of approximately one mile of I-44, from the I-44/Union Avenue grade separation to the Arkansas River. The project will widen I-44 from four through lanes to six through lanes. The project will also include spot improvements along this corridor to facilitate the ultimate configuration of I-44. These improvements include the replacement of the bridges on I-44 over 33rd W. Avenue, the bridge on Union Avenue over I-44, and two bridges on US-75 over I-44. All of this work is anticipated to be constructed within existing right-of-way, except for some minor acquisitions at the I-44 and Union Avenue grade separation. The project will include a new median barrier with pier protection for safety where I-44 runs under Union Avenue and US-75. All bridge replacements will include new bridge rail. Barrier walls will be installed in lieu of guardrail and cable barriers.

4.2 Types of Impacts and Affected Population

The Project improvements will address known deficiencies by providing a more convenient, efficient, and comfortable roadway network to existing users, and increase the network's attractiveness to new users. The new six-lane I-44 highway segment and spot improvements along the corridor will make it a high quality link in the region's transit network, in turn improving the travel time and safety of users as well as reducing vehicle emissions.

4.3 Project Cost and Schedule[3]

The project costs in **Table 1 and Table 2** below include capital costs and operation & maintenance costs necessary to improve and enhance the I-44 corridor. The project capital costs will be spent between 2016 and 2022, with use of the improved facility occurring immediately after completion and continuing for 20 years until 2042.

Table 1: Project Cost Summary Table

Cost Type	Cost in 2015 Dollars
Capital Cost	$109,770,621
Total Operation and Maintenance Costs (30-year period)	$1,000,000
TOTAL	$110,770,621

*Annual O&M costs are estimated at $50,000

[3] All cost estimates in this section are in millions of dollars of 2015, discounted to 2016 using a 7 percent real discount rate.

Table 2: Project Capital Cost Breakdown and Source of Funds

Use of Funds	Sources of Funds ($000)						
	State Funds		Federal Funds		FASTLANE Funds	Future Eligible Costs	Total Project Cost
	Previously Incurred	Future	Previously Incurred	Future			
Environmental and Engineering	$109	$526	$434	$2,102		$2,628	$3,171
ROW and Utilities		$44		$174		$218	$218
Construction		$20,000		$20,000	$60,000	$100,000	$100,000
Contingency and Other		$1,276		$1,276	$3,829	$6,382	$6,382
TOTAL	**$109**	**$21,846**	**$434**	**$23,553**	**$63,829**	**$109,228**	**$109,771**

4.4 Disruptions Due to Construction

The I-44/US75 Interchange Improvement Project in Tulsa County, Oklahoma, may have short-term construction impacts on traffic. Detours for access are expected to create minimal traffic delays, so no disruptions to traffic are included in the BCA. It is expected that any such impacts would not have a material effect on the project results.

4.5 FASTLANE Merit Criteria

The main benefit categories associated with the project are mapped into the four merit criteria set forth by the DOT in **Table 3** below.

Table 3: Expected Effects on Merit Outcomes and Benefit Categories

Merit Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
Economic	Travel Time Savings	The proposed project will reduce travel times for users of this corridor	Yes	Yes	
	Vehicle Operating Cost Savings	Fuel and non-fuel cost savings to the users. Non-fuel costs include all vehicles operating cost other than fuel (e.g., maintenance and repair, depreciation).	Yes	Yes	
	Inventory Cost Savings	Faster delivery times for truck drivers due to higher speeds along the corridor will lead to inventory cost savings			Yes
Mobility	Travel Time Reliability	The proposed project improvements will significantly reduce bottlenecks along the corridor			Yes
Safety	Accident Cost Reduction	Reduction in property losses, injuries, and deaths due to infrastructure improvements in the build scenario	Yes	Yes	
Community and Environmental	Emission Cost Reduction	Reduction in pollutants and green house gasses due to reductions in vehicle miles traveled (VMT) and vehicle hours traveled (VHT) in the build scenario	Yes	Yes	

5 General Assumptions

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

The monetized benefits and costs are estimated in 2015 dollars with future dollars discounted in compliance with FASTLANE requirements using a 7 percent real rate, and sensitivity testing at 3 percent.

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

- Input prices are expressed in 2015 dollars;
- The period of analysis begins in 2023 and ends in 2042. It includes construction years (2016 - 2022) and 20 years of operations (2023 – 2042);
- 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;
- Opening year demand is an input to the BCA and is assumed to be fully realized in 2023; and
- Unless specified otherwise, the results shown in this document correspond to the effects of the build scenario defined in Section 4.

6 Demand Projections

The current 2015 and future 2040 roadway twenty-four (24) hour volumes were developed using the Indian Nations Council of Government (INCOG), the Metropolitan Planning Organization for the Tulsa Metropolitan Area, Regional Travel Demand Model run specifically for this analysis. The INCOG Regional Travel Demand Model is a tool that is used to test various roadway improvements. This model was used in the BCA study to determine how much traffic the proposed widening of the I-44 would attract and the impact on the existing street network within the study area. In addition, a no-build scenario (current and forecast transportation network without proposed corridor improvements) was also modeled with modeled traffic provided as a twenty-four (24) hour traffic volume.

6.1 Methodology

The travel demand model runs provided no-build and build AADT volumes, speed and travel distances in 2010 and 2035 for each link on the corridor. These inputs were extracted at 5-mph speed bin increments and input into Cal-B/C Corridor to estimate benefits. Additional information on average vehicle occupancies came from US Census data for Oklahoma state averages.

Summary VMT/VHT input values are shown in **Table 4** below.

Table 4: Calibrated Travel Demand Model Runs for No-Build Conditions

Variable Name	Unit	Value	Source
Share of Trucks	Percentage	13%	Oklahoma bridge condition inventory
Base Year No Build VMT	VMT/day	27,412,830	INCOG Regional Travel Demand Model, April 2016
Forecast Year No Build VMT	VMT/day	37,632,232	
Base Year No Build VHT	VHT/day	653,684	
Forecast Year No Build VHT	VHT/day	1,146,757	
Base Year Build VMT	VMT/day	27,476,880	
Forecast Year Build VMT	VMT/day	37,720,159	
Base Year Build VHT	VHT/day	647,559	
Forecast Year Build VHT	VHT/day	1,136,011	

6.2 Assumptions

The assumptions used in the estimation of demand are summarized in **Table 5** and **Table 6** below.

Table 5: Assumptions used in the Estimation of Demand (No Build)

Speed (Miles per hour)	Base Year No Build **VMT**	Forecast Year No Build **VMT**	Base Year No Build **VHT**	Forecast Year No build **VHT**	Source
5	6,127	105,046	2,360	36,952	INCOG Regional Travel Demand Model, April 2016
10	59,912	402,539	6,950	55,845	
15	132,418	753,766	10,566	59,920	
20	336,386	1,630,206	18,840	92,005	
25	767,859	2,576,930	34,056	115,326	
30	1,688,045	3,736,261	60,747	135,103	
35	5,537,794	8,271,901	165,865	248,293	
40	1,930,927	2,952,813	51,532	78,518	
45	1,755,501	3,220,654	41,019	75,483	
50	1,987,242	2,886,468	41,802	60,643	
55	3,713,000	4,289,072	70,078	81,244	
60	2,613,060	1,955,787	45,652	34,066	
65	2,161,970	1,673,827	34,564	26,838	
70	4,722,589	3,176,962	69,652	46,523	

Table 6: Assumptions used in the Estimation of Demand (Build)

Speed (Miles per hour)	Base Year Build **VMT**	Forecast Year Build **VMT**	Base Year Build **VHT**	Forecast Year Build **VHT**	Source
5	6,490	111,412	2,318	36,587	INCOG Regional Travel Demand Model, April 2016
10	54,253	365,014	6,188	50,132	
15	127,714	727,979	10,153	58,058	
20	308,064	1,494,983	17,136	84,375	
25	766,356	2,575,384	33,699	115,061	
30	1,788,603	3,964,215	63,618	142,657	
35	5,188,678	7,760,956	154,214	232,759	
40	2,013,801	3,083,732	53,707	82,508	
45	1,645,074	3,022,167	38,350	71,154	
50	2,438,595	3,546,873	50,896	74,447	
55	3,762,768	4,352,471	70,530	82,444	
60	2,652,380	1,987,915	45,839	34,488	
65	1,943,190	1,506,489	30,913	24,201	
70	4,780,912	3,220,568	69,998	47,140	

6.3 Demand Projections

The resulting projections for Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT), and average speed are presented in the **Table 7** below using an annualization factor of 250 days. Projections by calendar year of operation are provided in **Table 18**.

Table 7: Demand Projections

	Variable Name	In Project Opening Year (2023)	Intermediate Year (2033)	Final Year of Analysis (2042)
No Build	Vehicle Miles Traveled (VMT)	7,772,953,701	8,794,893,924	9,714,640,125
	Vehicle Hours Traveled (VHT)	207,797,568	257,104,797	301,481,304
	Average Speed (MPH)	37.4	34.2	32.2
Build	Vehicle Miles Traveled (VMT)	7,791,115,159	8,815,443,089	9,737,338,226
	Vehicle Hours Traveled (VHT)	205,850,513	254,695,735	298,656,435
	Average Speed (MPH)	37.8	34.6	32.6

7 Benefits Measurement, Data and Assumptions

This section describes the measurement approach used for each benefit or impact category identified in **Table 3** and provides an overview of the associated methodology, assumptions, and estimates.

7.1 Merit Criteria

7.1.1 Economic Outcomes

The economic outcomes generated by the different project components improve the connectivity between home and work places and between production and consumption sites. At the same time, they increase the competitiveness of the United States by increasing efficiency in the movement of goods along the I-44 corridor. Travel time savings will be realized by passenger vehicles, which will be able to take advantage of higher average speeds compared to those experienced in the no-build scenario, in which the project does not occur. Truck drivers will also benefit and save time as well. It is estimated in the BCA that 13 percent of traffic in the study area is composed of trucks.

7.1.1.1 METHODOLOGY

Travel time savings and vehicle operating cost savings were calculated based on VMT and VHT data derived from the travel demand model for 2015 and 2040 (build and no-build scenarios). The data was then entered in the Cal-B/C model. Speed is calculated automatically from the VMT and VHT while average vehicle occupancy and percentage of trucks were exogenous inputs in the model.

7.1.1.2 ASSUMPTIONS

The assumptions used in the estimation of economic benefits are summarized in the table below.

Table 8: Assumptions used in the Estimation of Economic Benefits

Variable Name	Unit	Value	Source
Average Vehicle Occupancy (AVO) for State of Oklahoma	Persons per vehicle	1.08	Oklahoma state average vehicle occupancy; US Census
Share of Trucks	Percentage	13.00%	Oklahoma bridge condition inventory
Travel Time Cost - Automobile	Dollars per hour	$13.60	TIGER and FASTLANE BCA Resource Guide, March 2016, US DOT. HDR has inflated values from 214 Dollars to 2015 Dollars using Consumer Price Index.
Travel Time Cost - Truck	Dollars per hour	$26.98	
Real Annual Growth Rate of Value of Time	Percentage	1.00%	The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2015 Update), US DOT
Fuel Cost (Excludes Tax) - Automobile*	Dollars per gallon	$2.26	Annual Energy Outlook, 2015 Release, US Energy Information Administration (EIA). HDR has inflated values from 2013 Dollars to 2015 Dollars using Consumer Price Index
Fuel Cost (Excludes Tax) - Truck**	Dollars per gallon	$2.60	
Vehicle Operating Cost (Non-Fuel Cost) - Automobile	Dollars per mile	$0.404	Your Driving Costs, 2015 Edition, American Automobile Association (AAA). HDR has inflated value from 2014 Dollars to 2015 Dollars using Consumer Price Index
Vehicle Operating Cost (Non-Fuel Cost) - Truck	Dollars per mile	$0.417	American Transport Research Institute

***Retail Gasoline Prices**
**** Retail Diesel Prices**

7.1.1.3 BENEFIT ESTIMATES

The opening year savings in travel time is calculated at approximately $25.5 million, and total discounted savings in travel time is estimated to be $368.3 million. Due to an increase in VMT, the total discounted savings in vehicle operating cost is estimated to be -$52.0 million. Over the lifecycle of the projects, discounted savings associated with economic benefits total $316.3 million. Economic benefits results by calendar year of operation are shown in **Table 20**. They represent nearly 60 percent of the project's total benefits.

Table 9: Estimates of Economic Benefits, Millions of 2015 Dollars

Variable	In Project Opening Year (Discounted at 7 Percent)	Over the Project Lifecycle	
		In Constant Dollars	**Discounted at 7 Percent**
Travel Time Savings	$25.5	$909.2	$368.3
Vehicle Operating Cost Savings	-$6.38	-$114.47	-$52.01
Total	**$19.2**	**$794.7**	**$316.3**

7.1.2 Mobility Outcomes

No mobility impacts were monetized as part of this Benefit Cost Analysis, but travel time reliability and improved through speeds are tangible benefits that would be expected to accrue to road users as well as infrastructure reliability due to spot improvements to bridges and other components of the corridor.

7.1.3 Safety Outcomes

The Project would contribute to DOT's long-term safety outcomes through a reduction in the overall number of accidents. Nearly half of all crashes on the corridor occur during the peak commute periods, when congestion is at its maximum. The I-44/US-75 improvement project, and the ultimate full interchange reconstruction of which it is an initial element, is anticipated to relieve congestion near and through the interchange – an improvement which is known to correlate to reduced incidence of rear-end collisions.

7.1.3.1 METHODOLOGY

The number of accidents in the study area and their associated severity was provided for the past 5 years and converted to a rate per total vehicle miles driven in the study area over the same period. Actual accident statistics were provided by the Collision and Safety Branch of the Oklahoma Department of Transportation for both the 4-lane and 6-lane portions of I-44 (some sections if the I-44 corridor have been converted to six lanes, collision statistics were used for these segments as a proxy for the build condition).

7.1.3.2 ASSUMPTIONS

The assumptions used in the estimation of safety benefits are summarized in **Table 10** below.

Table 10: Assumptions used in the Estimation of Safety Benefits

Variable Name	Unit	Value	Source
Fatality Collision Rate - No Build	Fatalities or collisions per million VMT per day	0.02	Collision Rate Analysis, March 2016, ODOT Traffic Engineering Division Collision Analysis and Safety Branch
Visible Injury Collision Rate - No Build		0.85	
Property Damage Only Collision Rate - No Build		1.32	
Fatality Collision Rate - Build		0.01	
Visible Injury Collision Rate - Build		0.50	
Property Damage Only Collision Rate - Build		0.78	
AIS 1 Minor	Dollars per injury	$28,800	TIGER AND FASTLANE BCA Resource Guide, March 2016, US DOT.
AIS 2 Moderate		$451,200	
AIS 3 Serious		$1,008,000	
AIS 4 Severe		$2,553,600	
AIS 5 Critical		$5,692,800	
AIS 6 Not Survivable		$9,600,000	
PDO Crashes		$4,198	
Unknown - If Injured		$132,245	HDR Calculation Based on BCA Resource Guide, March 2016, US DOT
Cost per Injury Growth Factor*	Percentage	1.00%	Guidance on Treatment of the Economic Value of a Statistical Life, 2015, US DOT

7.1.3.3 BENEFIT ESTIMATES

Table 11 below indicates the monetized safety benefits in 2022 and for the duration of the period of study. The safety benefits derived total $414.1 million of the project lifecycle, discounted at 7 percent. Safety benefits results by calendar year of operation are shown in **Table 21**.

Table 11: Estimates of Safety Benefits, Millions of 2015 Dollars

Variable	In Project Opening Year (Discounted at 7 Percent)	Over the Project Lifecycle	
		In Constant Dollars	**Discounted at 7 Percent**
Accident Cost Reduction	$7.0	$258.8	$88.7

7.1.4 Community and Environmental Outcomes

The Project will contribute to environmental sustainability through reduction in vehicle and reducing congestion within the project corridor will improve access for some of the traditionally underserved populations in the region.

7.1.4.1 METHODOLOGY

There are five types of emissions measured in the analysis: carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxide (NOx), fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), and carbon dioxide (CO_2).

The emissions are monetized using values consistent with those found in NHTSA's *Final Regulatory Impact Analysis of the CAFE for MY2012-MY2016 Passenger Cars and Light Trucks* and in the TIGER and FASTLANE BCA Resource Guide (March 2016). Since Cal-B/C Corridor estimates impacts in US short tons, the monetization values for US short tons have been used. The analysis uses a value per ton of carbon dioxide equivalent (CO_{2e}) consistent with the guidance in the Federal Register. The value increases by 2 percent per year so the escalation factor (or uprater) is set to 2 percent.

7.1.4.2 ASSUMPTIONS

A summary of the emissions costs used in the model is provided in **Table 12** below.

Table 12: Assumptions used in the Estimation of Community and Environmental Benefits

Variable Name	Unit	Value	Source
Volatile Organic Compounds (VOC)	$ per short ton	$1,844	TIGER and FASTLANE BCA Resource Guide, March 2016, US DOT
Nitrogen Oxides (NOx)	$ per short ton	$7,266	
Fine Particulate Matter (PM)	$ per short ton	$332,405	
Sulfur Dioxide (SO2)	$ per short ton	$42,947	
Carbon (CO2)	$ per short ton	$39	

7.1.4.3 BENEFIT ESTIMATES

Overall, lifecycle emission reduction savings total to $18.2 million, discounted at 7 percent. Details of annual CO_2 emission reductions are shown in **Table 22**.

Table 13: Estimates of Community and Environmental Benefits, Millions of 2015 Dollars

Variable	In Project Opening Year (Discounted at 7 Percent)	Over the Project Lifecycle	
		In Constant Dollars	**Discounted at 7 Percent**
Emissions Cost Reduction	$0.2	$10.1	$4.5

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 (20 years). Benefits accrue during the full operation of the project.

Table 14: Overall Results of the Benefit Cost Analysis, Millions of 2015 Dollars

Project Evaluation Metric	7% Discount Rate	3% Discount Rate
Total Discounted Benefits	$409.5	$687.9
Total Discounted Costs	$103.1	$107.2
Net Present Value	$306.5	$580.7
Benefit / Cost Ratio	3.97	6.42
Internal Rate of Return (%)	24.81%	
Payback Period (years)	3 years	

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 24.8 percent. With a 7 percent real discount rate, the $103.1 million investment would result in $409.5 million in total benefits, a Net Present Value of $306.5 million, and a Benefit/Cost ratio of approximately 3.97. With a 3 percent real discount rate, the Net Present Value of the project would increase to $580.7 million, for a Benefit/Cost ratio of 6.42.

Table 15 below presents quantified benefit estimates by merit criteria in the build scenario. Benefits associated with the economic and safety merits criteria account for most of the total project benefits.

Table 15: Benefit Estimates by Merit Criteria for the Full Build Alternative

Merit Criteria	Benefit Categories	7% Discount Rate	3% Discount Rate
Economic	Travel Time Savings	$368,280,191	$601,346,996
	Vehicle Operating Cost Savings	-$52,012,456	-$79,644,910
Safety	Accident Cost Reduction	$88,748,058	$159,198,921
Community and Environmental	Emissions Cost Reduction	$4,516,979	$6,960,140
Total Benefit Estimates		**$409,532,771**	**$687,861,147**

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 Project using a 7 percent discount rate are summarized in the table below. The table provides the percentage changes in project NPV associated with variations in variables or parameters (listed in row), as indicated in the column headers.

For example, an increase in the Average Vehicle Occupancy factor from 1.08 (Oklahoma) to 1.25 (National) leads to a 19 percent increase in the project NPV. Changing the value of travel time for all motorists to lower and upper bounds recommended by USDOT results in a change of 25% to -32% in the NPV and a BCR of 4.71 to 3.02. Changes in the capital cost estimates of the project have less pronounced impacts on the NPV, but have more impact on the BCR which is highly sensitive to the project costs. Overall, the benefit-cost ratio is well above 1.0 for each of the sensitivity analyses presented below which suggests with a reasonable level of confidence that the project is a worthwhile investment from a societal standpoint.

Table 16: Assessment of BCA Sensitivity, Summary

Parameters	Change in Parameter Value	Current NPV	New NPV	Change in NPV	New B/C Ratio
Value of Travel Time	Lower Bound of Range Recommended by US DOT	$306,455,052	$208,124,956	-32.09%	3.02
	Upper Bound of Range Recommended by US DOT		$382,150,298	24.70%	4.71
Average Vehicle Occupancy (AVO)	National Average instead of Alabama AVO*		$364,425,082	18.92%	4.54
Capital Cost Estimate	25% Increase		$280,793,721	-8.37%	3.18
	25% Reduction		$332,116,383	8.37%	5.29

*National Average is 1.25, Source: Texas Transportation Institute, 2012 Urban Mobility Report, Page A-13

10 Supplementary Data Tables

This section breaks down all benefits associated with the four merit criteria (Economic, Mobility, Safety, Community & Environmental) in annual form for the I-44/US-75 Interchange Improvements in Tulsa County Project. Supplementary data tables are also provided for some specific benefit categories. For example, tables providing estimates of annual demand projections, average annual travel time, and annual CO_2 emissions saved are included.

Table 17: Annual Monetized Estimates of Total Project Benefits and Costs

Calendar Year	Project Year	Total Benefits $2015	Total Costs $2015	Undiscounted Net Benefits ($2015)	Discounted Net Benefit at 7%	Discounted Net Benefit at 3%
2016	1	$0	$542,581	-$542,581	-$542,581	-$542,581
2017	2	$0	$1,506,837	-$1,506,837	-$1,408,259	-$1,462,949
2018	3	$0	$1,311,953	-$1,311,953	-$1,145,911	-$1,236,642
2019	4	$0	$34,953,917	-$34,953,917	-$28,532,808	-$31,987,786
2020	5	$0	$34,583,333	-$34,583,333	-$26,383,459	-$30,726,843
2021	6	$0	$25,872,000	-$25,872,000	-$18,446,378	-$22,317,414
2022	7	$0	$11,000,000	-$11,000,000	-$7,329,764	-$9,212,327
2023 (opening)	8	$36,631,861	$50,000	$36,581,861	$22,781,345	$29,744,401
2024	9	$40,227,700	$50,000	$40,177,700	$23,383,787	$31,716,648
2025	10	$41,658,593	$50,000	$41,608,593	$22,632,318	$31,889,522
2026	11	$43,112,688	$50,000	$43,062,688	$21,890,887	$32,042,684
2027	12	$44,590,323	$50,000	$44,540,323	$21,160,787	$32,176,877
2028	13	$46,091,841	$50,000	$46,041,841	$20,443,128	$32,292,821
2029	14	$47,617,589	$50,000	$47,567,589	$19,738,858	$32,391,213
2030	15	$48,667,316	$50,000	$48,617,316	$18,854,633	$32,141,773
2031	16	$50,217,832	$50,000	$50,167,832	$18,183,131	$32,200,823
2032	17	$52,397,862	$50,000	$52,347,862	$17,732,032	$32,621,457
2033	18	$53,999,699	$50,000	$53,949,699	$17,079,093	$32,640,455
2034	19	$55,627,225	$50,000	$55,577,225	$16,443,295	$32,645,762
2035	20	$57,280,807	$50,000	$57,230,807	$15,824,795	$32,637,930
2036	21	$58,960,819	$50,000	$58,910,819	$15,223,675	$32,617,492
2037	22	$60,667,636	$50,000	$60,617,636	$14,639,952	$32,584,966
2038	23	$62,401,642	$50,000	$62,351,642	$14,073,586	$32,540,854
2039	24	$64,163,224	$50,000	$64,113,224	$13,524,485	$32,485,641
2040	25	$61,854,332	$50,000	$61,804,332	$12,184,515	$30,403,636
2041	26	$67,770,694	$50,000	$67,720,694	$12,477,482	$32,343,780
2042	27	$69,617,384	$50,000	$69,567,384	$11,979,190	$32,258,029
Total		$1,063,557,067	$110,770,621	$952,786,446	$266,461,815	$544,890,224

Table 18: Annual Demand Projections

Calendar Year	Project Year	Total Vehicle Miles Traveled (VMT)		Total Vehicle Hours Traveled (VHT)		Average Speed (MPH)	
		No-Build Scenario	Build Scenario	No-Build Scenario	Build Scenario	No-Build Scenario	Build Scenario
2023 (opening)	8	7,772,953,701	7,791,115,159	207,797,568	205,850,513	37	38
2024	9	7,875,147,723	7,893,547,952	212,728,291	210,735,035	37	37
2025	10	7,977,341,745	7,995,980,745	217,659,014	215,619,557	37	37
2026	11	8,079,535,768	8,098,413,538	222,589,737	220,504,079	36	37
2027	12	8,181,729,790	8,200,846,331	227,520,460	225,388,602	36	36
2028	13	8,283,923,812	8,303,279,124	232,451,183	230,273,124	36	36
2029	14	8,386,117,835	8,405,711,917	237,381,906	235,157,646	35	36
2030	15	8,488,311,857	8,508,144,710	242,312,629	240,042,168	35	35
2031	16	8,590,505,879	8,610,577,503	247,243,352	244,926,690	35	35
2032	17	8,692,699,902	8,713,010,296	252,174,075	249,811,213	34	35
2033	18	8,794,893,924	8,815,443,089	257,104,797	254,695,735	34	35
2034	19	8,897,087,946	8,917,875,882	262,035,520	259,580,257	34	34
2035	20	8,999,281,968	9,020,308,675	266,966,243	264,464,779	34	34
2036	21	9,101,475,991	9,122,741,468	271,896,966	269,349,301	33	34
2037	22	9,203,670,013	9,225,174,261	276,827,689	274,233,824	33	34
2038	23	9,305,864,035	9,327,607,054	281,758,412	279,118,346	33	33
2039	24	9,408,058,058	9,430,039,847	286,689,135	284,002,868	33	33
2040	25	9,510,252,080	9,532,472,640	291,619,858	288,887,390	33	33
2041	26	9,612,446,102	9,634,905,433	296,550,581	293,771,912	32	33
2042	27	9,714,640,125	9,737,338,226	301,481,304	298,656,435	32	33
Total		174,875,938,254	175,284,533,847	5,092,788,720	5,045,069,474		

Table 19: Annual Average Travel Time (Hours)

Calendar Year	Project Year	No-Build	Build	Total Person-Hours of Time Saved
2023 (opening)	8	16,030,098	15,879,897	150,201
2024	9	16,410,468	16,256,703	153,765
2025	10	16,790,838	16,633,509	157,330
2026	11	17,171,208	17,010,315	160,894
2027	12	17,551,578	17,387,121	164,458
2028	13	17,931,948	17,763,927	168,022
2029	14	18,312,318	18,140,733	171,586
2030	15	18,692,689	18,517,539	175,150
2031	16	19,073,059	18,894,345	178,714
2032	17	19,453,429	19,271,151	182,278
2033	18	19,833,799	19,647,957	185,842
2034	19	20,214,169	20,024,763	189,406
2035	20	20,594,539	20,401,569	192,970
2036	21	20,974,909	20,778,375	196,534
2037	22	21,355,279	21,155,181	200,098
2038	23	21,735,649	21,531,987	203,662
2039	24	22,116,019	21,908,793	207,226
2040	25	22,496,389	22,285,599	210,790
2041	26	22,876,759	22,662,405	214,354
2042	27	23,257,129	23,039,211	217,918
Total		392,872,273	389,191,074	3,681,199

Table 20: Economic - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits $2015	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	$25,116,391	$15,641,225.75	$20,421,923.98
2024	9	$28,220,096	$16,424,352.53	$22,277,204.01
2025	10	$29,416,825	$16,000,803.64	$22,545,546.78
2026	11	$30,633,224	$15,572,377.78	$22,793,995.63
2027	12	$31,869,571	$15,141,003.58	$23,023,256.12
2028	13	$33,126,147	$14,708,405.33	$23,234,012.86
2029	14	$34,403,237	$14,276,120.05	$23,426,930.02
2030	15	$35,701,129	$13,845,513.29	$23,602,651.98
2031	16	$37,020,116	$13,417,793.73	$23,761,803.81
2032	17	$39,119,515	$13,251,133.22	$24,377,988.51
2033	18	$40,485,860	$12,816,786.48	$24,494,611.19
2034	19	$41,874,200	$12,389,064.76	$24,596,679.19
2035	20	$43,284,842	$11,968,619.53	$24,684,740.61
2036	21	$44,718,098	$11,556,006.41	$24,759,326.88
2037	22	$46,174,285	$11,151,694.00	$24,820,953.26
2038	23	$47,653,720	$10,756,072.04	$24,870,119.26
2039	24	$49,156,729	$10,369,458.84	$24,907,309.11
2040	25	$50,683,640	$9,992,108.23	$24,932,992.19
2041	26	$52,234,783	$9,624,215.87	$24,947,623.43
2042	27	$53,810,497	$9,265,925.05	$24,951,643.72
Total		$794,702,904	$258,168,680	$477,431,313

Table 21: Safety - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits 2015 Dollars	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	11,219,189	6,986,747	9,122,228
2024	9	11,405,388	6,638,039	9,003,518
2025	10	11,594,188	6,306,470	8,885,980
2026	11	11,785,624	5,991,213	8,769,611
2027	12	11,979,729	5,691,483	8,654,411
2028	13	12,176,537	5,406,528	8,540,378
2029	14	12,376,084	5,135,635	8,427,511
2030	15	12,578,404	4,878,122	8,315,807
2031	16	12,783,533	4,633,341	8,205,264
2032	17	12,991,507	4,400,673	8,095,878
2033	18	13,202,362	4,179,530	7,987,646
2034	19	13,416,135	3,969,350	7,880,565
2035	20	13,632,863	3,769,600	7,774,631
2036	21	13,852,583	3,579,771	7,669,840
2037	22	14,075,335	3,399,378	7,566,186
2038	23	14,301,157	3,227,959	7,463,667
2039	24	14,530,088	3,065,077	7,362,276
2040	25	10,663,724	2,102,317	5,245,845
2041	26	14,997,435	2,763,265	7,162,858
2042	27	15,235,932	2,623,559	7,064,821
Total		$258,797,798	$88,748,058	$159,198,921

Table 22: Annual CO_2 Emissions Saved

Calendar Year	Project Year	Annual CO2 Emissions Saved (Short Tons)
2023 (opening)	8	891
2024	9	4,777
2025	10	5,241
2026	11	5,704
2027	12	6,168
2028	13	6,632
2029	14	7,095
2030	15	6,513
2031	16	6,858
2032	17	4,707
2033	18	5,038
2034	19	5,369
2035	20	5,700
2036	21	6,030
2037	22	6,361
2038	23	6,692
2039	24	7,023
2040	25	7,354
2041	26	7,685
2042	27	8,016
Total		119,853

Table 23: Community and Environmental - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits $2015	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	$296,281	$184,509.13	$240,903.84
2024	9	$602,217	$350,496.03	$475,396.00
2025	10	$647,580	$352,240.83	$496,316.45
2026	11	$693,840	$352,713.31	$516,282.47
2027	12	$741,024	$352,055.05	$535,331.33
2028	13	$789,157	$350,395.16	$553,498.86
2029	14	$838,268	$347,851.32	$570,819.56
2030	15	$387,783	$150,388.86	$256,370.13
2031	16	$414,183	$150,118.92	$265,848.20
2032	17	$286,840	$97,162.49	$178,748.94
2033	18	$311,477	$98,605.60	$188,448.63
2034	19	$336,891	$99,673.75	$197,887.68
2035	20	$363,103	$100,400.97	$207,072.49
2036	21	$390,137	$100,818.76	$216,009.28
2037	22	$418,016	$100,956.30	$224,704.11
2038	23	$446,764	$100,840.55	$233,162.86
2039	24	$476,406	$100,496.46	$241,391.22
2040	25	$506,968	$99,947.07	$249,394.76
2041	26	$538,475	$99,213.65	$257,178.86
2042	27	$570,955	$98,315.85	$264,748.75
Total		$10,056,365	$3,687,200	$6,369,514