Cost-Effectiveness Analysis Supplementary Documentation

INFRA Grants Program

I-44 Corridor Improvements in Tulsa County

Oklahoma Department of Transportation (ODOT)

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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, and widen from four to six lanes, approximately one mile of I-44, from the I-44/Union Avenue grade separation to the Arkansas River. The project will also incorporate the following bridge improvements adjacent to or within this I-44 highway segment: on I-44 over 33rd W. Avenue, on Union Avenue over I-44, and US-75 over I-44.

The various components of this project are intended to facilitate the ultimate configuration of the local 2.5-mile stretch of I-44, including the I-44/US-75 interchange, 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 benefits, which include the following:

- Significant travel time savings for private and commercial drivers in the vicinity of the Project and along nearby segments of 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;
- Reduce emissions for pollutants such as volatile organic compounds (VOC), nitrogen oxides (NO_x), fine particulate matter (PM), Sulfur Dioxide (SO_x), and Carbon Dioxide (CO_2); and
- Reduce ongoing maintenance costs of current infrastructure.

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 (Local Impacts), Millions of 2016 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
Existing infrastructure within the I-44 Corridor remains in poor condition and becomes increasingly expensive to maintain, creating traffic growth constraints, and hindering connectivity in the region. Travel Delays for Passenger Vehicles and Trucks due to congestion on the I-44 persist and worsen over the study period.	Increase the capacity of I-44 by widening I-44 from four through lanes to six through lanes from the I-44/ Union Avenue grade separation to the Arkansas River. The project will also incorporate the following bridge improvements adjacent to, or within, this I-44 highway segment: on I-44 over 33rd W. Avenue, on Union Avenue over I-44, and US-75 over I-44.	Improved travel speeds, reduced long-term congestion, fuel savings	Passenger vehicles, trucks	Travel Time and Vehicle Operating Cost Savings	$47.30	Pg. 15
		Emission Savings	Passenger vehicles, trucks	Emissions Cost Reduction	$0.23	Pg. 18
		Improved Safety	Passenger vehicles, trucks	Accident Cost Reduction	$37.29	Pg. 17
		Reduced maintenance and rehabilitation costs	State Governments	Maintenance Cost Savings	$0.06	Pg. 15
		Increased useful life of assets	State Governments	Residual Value of Assets	$3.94	Pg. 15

The period of analysis used in the monetization of benefits and costs corresponds to 37 years, including 7 years of project development and construction activities, and 30 years of operation. The total undiscounted project capital costs[1] are $109.8 million dollars with an anticipated $7.5 thousand in ongoing annual maintenance cost savings once the project is complete.

A summary of the relevant data and calculations used to derive the monetized benefits and costs of the project are shown in **Table ES-2** (in 2016 dollars). Based on the analysis presented in the rest of this document, the project is expected to generate $88.8 million in discounted benefits and $82.3 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value (NPV) of $6.5 million and a Benefit/Cost Ratio of 1.08.

[1] Total project capital costs do not include operations & maintenance (O&M) costs. Cost data was provided in 2016 Dollars. Annual monetized estimates of total project costs are presented in section 10.

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

Calendar	Project Year	Total Benefits	Travel Time Savings	Vehicle Operating Cost Savings	Safety	O&M Cost Reduction	Residual Value of Assets	Emissions	Total Costs
2016	1	$0	$0	$0	$0	$0	$0	$0	$1,162,903
2017	2	$0	$0	$0	$0	$0	$0	$0	$1,022,303
2018	3	$0	$0	$0	$0	$0	$0	$0	$941,003
2019	4	$0	$0	$0	$0	$0	$0	$0	$15,009,950
2020	5	$0	$0	$0	$0	$0	$0	$0	$35,227,957
2021	6	$0	$0	$0	$0	$0	$0	$0	$15,818,311
2022	7	$0	$0	$0	$0	$0	$0	$0	$13,117,613
2023	8	$6,163,691	$7,754,999	($4,523,385)	$2,933,231	$4,720	$0	($5,875)	$0
2024	9	$5,857,814	$7,223,411	($4,128,239)	$2,729,411	$4,411	$0	$28,820	$0
2025	10	$5,516,816	$6,728,186	($3,787,495)	$2,539,704	$4,123	$0	$32,298	$0
2026	11	$5,062,041	$6,266,843	($3,588,477)	$2,363,138	$3,853	$0	$16,685	$0
2027	12	$4,814,005	$5,837,066	($3,253,654)	$2,198,804	$3,601	$0	$28,188	$0
2028	13	$4,683,745	$5,436,700	($2,851,687)	$2,045,858	$3,365	$0	$49,508	$0
2029	14	$4,367,492	$5,063,737	($2,651,267)	$1,903,513	$3,145	$0	$48,364	$0
2030	15	$4,039,207	$4,716,305	($2,457,307)	$1,771,036	$2,939	$0	$6,233	$0
2031	16	$3,852,712	$4,392,659	($2,197,219)	$1,647,747	$2,747	$0	$6,778	$0
2032	17	$3,491,581	$4,091,174	($2,137,419)	$1,533,008	$2,567	$0	$2,250	$0
2033	18	$3,305,609	$3,810,336	($1,936,713)	$1,426,231	$2,399	$0	$3,356	$0
2034	19	$3,115,746	$3,548,734	($1,765,812)	$1,326,863	$2,243	$0	$3,719	$0
2035	20	$2,883,307	$3,305,052	($1,659,468)	$1,234,392	$2,096	$0	$1,235	$0
2036	21	$2,689,384	$3,088,834	($1,550,904)	$1,148,342	$1,959	$0	$1,154	$0
2037	22	$2,508,494	$2,886,760	($1,449,443)	$1,068,267	$1,831	$0	$1,079	$0
2038	23	$2,339,761	$2,697,907	($1,354,620)	$993,755	$1,711	$0	$1,008	$0
2039	24	$2,182,370	$2,521,408	($1,266,000)	$924,420	$1,599	$0	$942	$0
2040	25	$2,035,558	$2,356,456	($1,183,177)	$859,904	$1,494	$0	$881	$0
2041	26	$1,898,615	$2,202,296	($1,105,773)	$799,873	$1,397	$0	$823	$0
2042	27	$1,770,877	$2,058,220	($1,033,433)	$744,016	$1,305	$0	$769	$0
2043	28	$1,651,728	$1,923,570	($965,825)	$692,044	$1,220	$0	$719	$0
2044	29	$1,540,588	$1,797,729	($902,640)	$643,688	$1,140	$0	$672	$0
2045	30	$1,436,922	$1,680,121	($843,589)	$598,697	$1,065	$0	$628	$0
2046	31	$1,340,225	$1,570,206	($788,401)	$556,838	$996	$0	$587	$0
2047	32	$1,250,031	$1,467,483	($736,823)	$517,893	$931	$0	$548	$0
2048	33	$1,165,902	$1,371,479	($688,620)	$481,661	$870	$0	$512	$0
2049	34	$1,087,430	$1,281,756	($643,570)	$447,953	$813	$0	$479	$0
2050	35	$1,014,236	$1,197,903	($601,467)	$416,594	$760	$0	$448	$0
2051	36	$945,965	$1,119,535	($562,119)	$387,420	$710	$0	$418	$0
2052	37	$4,821,381	$1,046,295	($525,345)	$360,281	$663	$3,939,096	$391	$0
Total		**$88,833,235**	**$100,443,163**	**($53,139,892)**	**$37,294,581**	$62,672	$3,939,096	**$233,616**	**$82,300,040**

In addition to the monetized benefits presented in **Table ES-2**, 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.

Travel Time Reliability

A 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.

All results for the Benefit Cost Analysis are estimated for the local segments in the immediate vicinity of the Project which will be the most directly impacted. However, in addition to these localized benefits, a select link analysis of the Project’s impacts has demonstrated significant benefits to the broader transportation network in the region. Given the strategic importance of this segment for the region and the state in general, the estimated regional benefits are briefly discussed and summarized in Sections 7 and 8.

2 Introduction

This document provides detailed technical information on the economic analyses conducted in support of the INFRA Grant Application for the I-44 Corridor Improvements 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 "Support for National and Regional Economic Vitality" 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 INFRA guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the build and no-build scenarios
- Assessing benefits with respect to the "Support for National and Regional Economic Vitality" merit criteria identified in the INFRA BCA guidance;
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;
- Using USDOT 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 USDOT (7 percent with 3 percent as a 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

[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 ODOT expects the project to have a longer useful life.

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).*

For this INFRA 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 INFRA BCA Resource Guide (July 2017). 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. 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 input into the Final Calculations page of Cal-B/C Corridor to be included in the BCA. Furthermore, the residual value of the capital assets expected at the end of the study period was included as a final-year benefit.

4 Project Overview

The I-44 Corridor Improvements project in the City of Tulsa, Tulsa County, Oklahoma, is located on a portion of the Primary Highway Freight Network, from the interchange of I-44 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 the 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 for this one-mile segment. The project will also 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. Mainline I-44 will have standard 12-foot inside and outside shoulders. 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 other improvements along the corridor will make it a high quality link in the region's transportation network, in turn improving the travel time and safety of users as well as reducing vehicle emissions.

4.3 Project Cost and Schedule

The project costs in **Table 1 and Table 2** below include capital 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 30 years until 2052. Annual maintenance cost savings are estimated at $7,500, including $50,000 in incremental expenditures on maintenance, $43,000 in rehabilitation expenses, and $100,000 in maintenance cost savings compared to the base case.

Table 1: Project Cost Summary Table

Cost Type	Cost in 2016 Dollars
Capital Cost	$109,770,621
Total Costs	**$109,770,621**

Table 2: Project Capital Cost Breakdown and Source of Funds

Use of Funds	Sources of Funds ($000)						
	State Funds		Federal Funds		INFRA Funds	Future Eligible Costs	Total Project Cost
	Previously Incurred	Future	Previously Incurred	Future			
Environmental and Engineering	$405	$229	$1621	$916		$1,145	$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	**$405**	**$21,549**	**$1,621**	**$22,367**	**$63,829**	**$107,745**	**$109,771**

4.4 Disruptions Due to Construction

The Project 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 INFRA Merit Criteria

The main benefit categories associated with the project, and in line with the "Support for National and Regional Economic Vitality" merit criteria set forth by the DOT, are presented in **Table 3** below.

Table 3: Expected Effects on Merit Outcomes and Benefit Categories

Merit Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
Support for National and Regional Economic Vitality	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
	Travel Time Reliability	The proposed project improvements will significantly reduce bottlenecks along the corridor			Yes
	Accident Cost Reduction	Reduction in property losses, injuries, and deaths due to infrastructure improvements in the build scenario	Yes	Yes	
	Emission Cost Reduction	Reduction in pollutants and greenhouse gasses due to reductions in vehicle miles traveled (VMT) and vehicle hours traveled (VHT) in the build scenario	Yes	Yes	
	Maintenance Cost Savings	The project will improve the condition of existing infrastructure and reduce the annual costs needed to maintain it in a state of good repair	Yes	Yes	
	Residual Values of Assets	New infrastructure will still have a useful life beyond the study period	Yes	Yes	

5 General Assumptions

The BCA measures benefits against costs throughout a period of analysis from the start of project development and construction activities, through 30 years of operations.

The monetized benefits and costs are estimated in 2016 dollars with future dollars discounted in compliance with INFRA 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 2016 dollars;
- The period of analysis begins in 2017 (although it accounts for some of the costs incurred in 2016) and ends in 2052. It includes design and construction years (2017 - 2022) and 30 years of operations (2023 - 2052);
- 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 2017 and future 2052 roadway twenty-four (24) hour volumes were developed using the Indian Nations Council of Governments (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 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 the proposed Project improvements) was also modeled with traffic estimates provided as a twenty-four (24) hour traffic volume. The travel demand model was originally run for the FY2016/17 FASTLANE program, and as it stands, represents a conservative demand forecast due to new developments in the region that are expected to increase traffic and further exacerbate the current challenges.

Specifically, the Oklahoma Turnpike Authority (OTA) recently announced that it intends to complete the extension of the Gilcrease Expressway, a new north-south highway from the I-44/I-244 interchange north to Edison Street (north of US-412), tying into the current project area at its western end. This project will consist of approximately 5.6 miles of a 4-lane, new alignment limited access expressway with grade-separated interchanges and a new bridge across the Arkansas River. Much of the right-of-way for this corridor has already been purchased by the City of Tulsa, and construction is anticipated to begin as early as 2018.

The effect of the Gilcrease Expressway expansion on the I-44 corridor is an increase in traffic on the order of approximately 10,000 trips per day. Many of these trips are expected to be commercial trucks, as the Gilcrease Expressway will serve the industrial and refinery businesses located in west Tulsa. This anticipated increase in trips will add to the burden on I-44 and increase the need to reduce the existing bottleneck for freight and passenger traffic on this congested corridor.

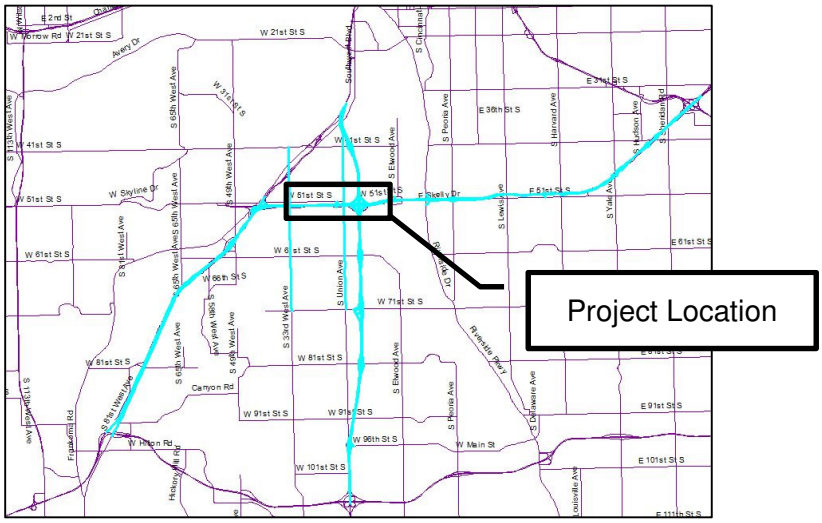
6.1 Methodology

The travel demand model runs provided no-build and build AADT volumes, speed and travel distances in 2010 and 2035 (which were the years for which it was calibrated) for each link in the immediate vicinity of the project as illustrated in the figure below. These inputs were extracted at 5-mph speed bin increments and input into Cal-B/C Corridor to estimate benefits in other years, including the base (2017) and the final (2052) study year. AADT volumes were assumed to remain constant beyond 2035, the final year of the travel demand model runs. 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

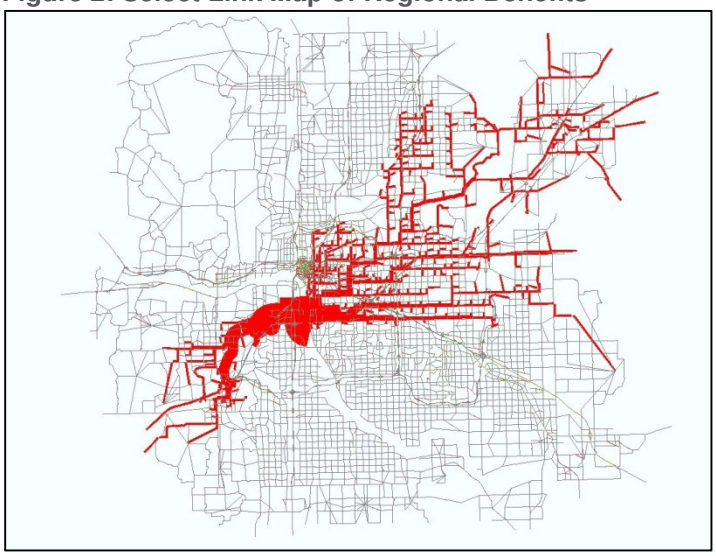
Variable Name	Unit	Value	Source
Share of Trucks	Percentage	14%	I-44 Preliminary Engineering Study
Base Year No Build VMT	VMT/day	2,769,320	INCOG Regional Travel Demand Model, April 2016
Forecast Year No Build VMT	VMT/day	2,484,224	
Base Year No Build VHT	VHT/day	67,549	
Forecast Year No Build VHT	VHT/day	64,528	
Base Year Build VMT	VMT/day	2,864,761	
Forecast Year Build VMT	VMT/day	2,569,839	
Base Year Build VHT	VHT/day	62,134	
Forecast Year Build VHT	VHT/day	59,355	

Figure 1: Local Impacts Map of the I-44 Corridor Improvements Project



All results for the Benefit Cost Analysis are estimated for the local segments in the immediate vicinity of the project which will be the most directly impacted. However, in addition to these localized benefits, a select link analysis of the Project's impacts has demonstrated significant benefits to the broader transportation network in the region. Given the strategic importance of this segment for the region and the state in general, it is anticipated that the project will benefit the regional flows as illustrated below.

Figure 2: Select Link Map of Regional Benefits



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	5,374	2,345	1,537	588	INCOG Regional Travel Demand Model, April 2016
10	17,931	14,242	2,391	1,784	
15	55,704	58,718	4,197	4,575	
20	26,736	84,273	1,322	4,452	
25	215,378	117,755	9,297	5,076	
30	278,090	110,665	7,928	4,144	
35	247,833	98,616	4,911	3,032	
40	192,015	145,495	4,310	3,980	
45	231,018	270,331	5,119	6,234	
50	276,830	297,519	5,919	6,278	
55	371,943	283,180	6,510	5,371	
60	400,347	477,954	6,992	8,354	
65	284,677	456,172	4,601	7,264	
70	165,442	66,960	2,514	1,001	

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	2,821	1,569	823	363	INCOG Regional Travel Demand Model, April 2016
10	11,167	11,305	1,562	1,345	
15	10,327	13,876	807	1,015	
20	18,151	72,926	1,057	4,106	
25	142,638	99,405	5,421	3,414	
30	763,247	387,155	19,076	11,501	
35	251,854	127,741	3,226	2,297	
40	255,107	246,394	4,605	4,906	
45	171,705	256,111	4,097	5,755	
50	288,842	395,692	6,697	8,192	
55	505,165	490,245	9,247	8,801	
60	125,090	190,356	2,400	3,308	
65	73,805	150,750	1,336	2,433	
70	244,842	126,314	4,175	1,918	

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 20**.

Table 7: Demand Projections

	Variable Name	In Project Opening Year (2023)	Intermediate Year (2038)	Final Year of Analysis (2052)
No Build	Vehicle Miles Traveled (VMT)	655,267,597	621,056,122	621,056,122
	Vehicle Hours Traveled (VHT)	16,183,246	15,533,436	15,533,436
	Average Speed (MPH)	40.49	39.98	39.98
Build	Vehicle Miles Traveled (VMT)	677,850,394	642,459,873	642,459,873
	Vehicle Hours Traveled (VHT)	15,459,611	14,838,857	14,838,857
	Average Speed (MPH)	43.85	43.30	43.30

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 Support for National and Regional Economic Vitality

7.1.1 Economic Benefits

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 that 14 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 each year of the study period (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.

Annual maintenance cost savings are estimated at $7,500, including $50,000 in incremental expenditures on maintenance, $43,000 in rehabilitation expenses, and $100,000 in maintenance cost savings compared to the base case, based on historical expenditures on the highway segment by ODOT. A residual value of assets was calculated using a straight-line depreciation method based on useful life estimates provided by the engineering team for each type of investment (e.g. 30 years for pavement, 75 years for bridge structures, etc.) Given that new infrastructure would reduce the future rehabilitation costs on an incremental basis, no adjustments had to be made in the residual value.

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	14%	I-44 Preliminary Engineering Study
Travel Time Cost - Automobile	Dollars per hour	$14.10	Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis https://www.transportation.gov/officepolicy/transportation-policy/reviseddepartmental-guidance-valuationtravel-time-economic
Travel Time Cost - Truck	Dollars per hour	$27.20	

Variable Name	Unit	Value	Source
Fuel Cost (Excludes Tax) - Automobile*	Dollars per gallon	$1.89	Annual Energy Outlook, 2017 Release, US Energy Information Administration (EIA).
Fuel Cost (Excludes Tax) - Truck**	Dollars per gallon	$2.14	
Vehicle Operating Cost (Non-Fuel Cost) - Automobile	Dollars per mile	$0.33	Your Driving Costs, 2016 Edition, American Automobile Association (AAA).
Vehicle Operating Cost (Non-Fuel Cost) - Truck	Dollars per mile	$0.56	American Transport Research Institute
Annual Maintenance Cost Savings	Dollars per year	$7,580	Calculated based on cost savings over no build case less rehabilitation costs and Maintenance costs in the build case based on historical expenditures by Oklahoma DOT
Useful Life of Bridges	years	75	Oklahoma DOT
Useful Life of Pavement	years	30	

*Retail Gasoline Prices

** Retail Diesel Prices

7.1.1.3 BENEFIT ESTIMATES

The opening year savings in travel time is calculated at approximately $8 million, and total discounted savings in travel time is estimated to be $100 million. Despite vehicle operating cost savings to existing road users of approximately $12 million, an increase in overall VMT results in an increase in total discounted vehicle operating costs of $53 million, as shown in **Table 9**. Over the lifecycle of the Project, discounted savings associated with economic benefits total $51 million. Economic benefits results by calendar year of operation are shown in **Table 22,** with a breakout of travel time and vehicle operating cost benefits in Tables 26 and 27. They represent nearly 58 percent of the project's total benefits.

Table 9: Estimates of Economic Benefits, Millions of 2016 Dollars

Variable	In Project Opening Year (Discounted at 7 Percent)	Over the Project Lifecycle	
		In Constant Dollars	Discounted at 7 Percent
Travel Time Savings	$7.8	$361.8	$100.4
Vehicle Operating Cost Savings	($4.5)	($186.9)	($53.1)
Maintenance Costs	$0.0	$0.2	$0.1
Residual Value of Assets	$0.0	$45.0	$3.9
Total	**$3.2**	**$220.2**	**$51.3**

**Due to increase in VMT; adjusting for the same VMT as the no build case results in a $12M benefit*

7.1.2 Safety Benefits

The Project would contribute to economic vitality from safety benefits 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 Corridor Improvements 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.

7.1.2.1 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 of the I-44 corridor, such as the portion east of the Arkansas River and the portion between SH-51 and US-169, have been converted to six lanes. Collision statistics were used for these segments as a proxy for the build condition).

7.1.2.2 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	0.023	Collision Rate Analysis, March 2016, ODOT Traffic Engineering Division Collision Analysis and Safety Branch.
Visible Injury Collision Rate - No Build		0.84	
Property Damage Only Collision Rate - No Build		1.32	
Fatality Collision Rate - Build		0.007	
Visible Injury Collision Rate - Build		0.50	
Property Damage Only Collision Rate - Build		0.78	
Value of a Statistical Life	Dollars/event	$9,600,000	Guidance on Treatment of the Economic Value of a Statistical Life, 2016, US DOT. *https://www.transportation.gov/officepolicy/transportation-policy/reviseddepartmental-guidance-on-valuation-of-astatistical-life-in-economic-analysis*
Average PDO Cost per Vehicle		$4,252	
Average Cost per Accident Injury		$110,663	HDR Calculations based on weighted average of injury types using valuations provided in 2017 US DOT Guidance. Distribution of injuries gathered from 2014 Traffic Safety Facts, FARS/GES Annual Report, Publication #812139, Table 54 on page 106.
Cost per Injury Growth Factor	Percentage	0.00%	No escalation based on latest US DOT Guidance.

7.1.2.3 BENEFIT ESTIMATES

Table 11 below indicates the monetized safety benefits in 2023 and for the duration of the period of study. The safety benefits accounted for a total of $37.3 million over the project lifecycle, discounted at 7 percent. Safety benefits results by calendar year of operation are shown in **Table 24**.

Table 11: Estimates of Safety Benefits, Millions of 2016 Dollars

Variable	In Project Opening Year (Discounted at 7 Percent)	Over the Project Lifecycle	
		In Constant Dollars	Discounted at 7 Percent
Accident Cost Reduction	$2.9	$132.4	$37.3

7.1.3 Emission Benefits

The Project will contribute to economic vitality from environmental sustainability by reducing congestion within the project vicinity and improving access and air quality for some of the traditionally underserved populations in the region. While increased VMT's from induced traffic flows generate additional emissions, the improved traffic flows result in an overall net reduction in greenhouse gas emissions and air pollutants.

7.1.3.1 METHODOLOGY

There are five types of emissions measured in the analysis: volatile organic compounds (VOC), nitrogen oxide (NOx), fine particulate matter (PM), sulfur dioxide (SO_2), and carbon dioxide (CO_2).

The emissions are monetized using values consistent with those found in the TIGER and INFRA BCA Resource Guide (July 2017). The value for carbon was set to $0 due to a lack of US DOT guidance. Since Cal-B/C Corridor estimates impacts in US short tons, the monetization values for US short tons have been used.

7.1.3.2 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 Emission Benefits

Variable Name	Unit	Value	Source
Volatile Organic Compounds (VOC)	$ per short ton	$1,872	Corporate Average Fuel Economy for MY2017-MY2025 Passenger Cars and Light Trucks (August 2012), page 922, Table VIII16, "Economic Values Used for Benefits Computations (2010 dollars)" http://www.nhtsa.gov/staticfiles/rulemakin g/pdf/cafe/FRIA_2017-2025.pdf
Nitrogen Oxides (NOx)	$ per short ton	$7,377	
Fine Particulate Matter (PM)	$ per short ton	$337,460	
Sulfur Dioxide (SO2)	$ per short ton	$43,600	
Carbon (CO2)	$ per short ton	$0	

7.1.3.3 BENEFIT ESTIMATES

Overall, lifecycle emission reduction savings total to $0.23 million, discounted at 7 percent. Details of annual CO_2 emission reductions are shown in **Table 25**.

Table 13: Estimates of Community and Environmental Benefits, Millions of 2016 Dollars

Variable	In Project Opening Year (Discounted at 7 Percent)	Over the Project Lifecycle	
		In Constant Dollars	Discounted at 7 Percent
Emissions Cost Reduction	($0.01)	$0.56	$0.23

8 Summary of Findings and BCA Outcomes

The tables below summarize the BCA findings for impacts in the immediate vicinity of the project. Annual costs and benefits are computed over the lifecycle of the project (30 years). Benefits accrue during the full operation of the project.

Table 14: Overall Results of the Benefit Cost Analysis (Local Impacts), Millions of 2016 Dollars

Project Evaluation Metric	7% Discount Rate	3% Discount Rate
Total Discounted Benefits	$88.8	$184.2
Total Discounted Costs	$82.3	$96.7
Net Present Value	$6.5	$87.5
Benefit / Cost Ratio	1.08	1.90
Internal Rate of Return (%)	6.0%	
Payback Period (years)	11 years	

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 6.0 percent. With a 7 percent real discount rate, the $82.3 million investment would result in $88.8 million in total benefits, a Net Present Value of $6.5 million, and a Benefit/Cost ratio of approximately 1.08. With a 3 percent real discount rate, the Net Present Value of the project would increase to $87.5 million, for a Benefit/Cost ratio of 1.90.

Table 15 below presents quantified benefit estimates for the "Support for National and Regional Economic Vitality" merit criteria in the build scenario. Economic and safety benefits account for most of the total project benefits.

Table 15: Benefit Estimates by Merit Criteria for the Full Build Alternative (Local Impacts)

Merit Criteria	Benefit Categories	7% Discount Rate	3% Discount Rate
Support for National and Regional Economic Vitality	Travel Time Savings	$100,443,163	$198,586,081
	Vehicle Operating Cost Savings	($53,139,892)	($103,601,407)
	Accident Cost Reduction	$37,294,581	$73,174,678
	Emissions Cost Reduction	$233,616	$378,430
	Maintenance Cost Savings	$62,672	$124,418
	Residual Value of Assets	$3,939,096	$15,526,459
Total Benefit Estimates		**$88,833,235**	**$184,188,659**

In addition to these localized benefits, a select link analysis of the Project's impacts has demonstrated significant benefits to the broader transportation network in the region. For example, the Gilcrease Expressway, once built, is expected to add approximately 10,000 vehicles per day to I-44 and in turn significantly enhance the overall benefits of this project. Given the strategic importance of this segment for the region and the state in general, the estimated regional benefits are briefly summarized below.

Table 16: Overall Results of the Benefit Cost Analysis (Regional Impacts), Millions of 2016 Dollars

Project Evaluation Metric	7% Discount Rate	3% Discount Rate
Total Discounted Benefits	$366.5	$754.5
Total Discounted Costs	$82.3	$96.7
Net Present Value	$284.2	$657.7
Benefit / Cost Ratio	4.45	7.80
Internal Rate of Return (%)	24.4%	
Payback Period (years)	3 years	

Table 17: Benefit Estimates by Merit Criteria for the Full Build Alternative (Regional Impacts)

Merit Criteria	Benefit Categories	7% Discount Rate	3% Discount Rate
Support for National and Regional Economic Vitality	Travel Time Savings	$351,530,661	$713,411,937
	Vehicle Operating Cost Savings	($41,598,059)	($80,964,296)
	Accident Cost Reduction	$50,433,063	$102,980,254
	Emissions Cost Reduction	$2,121,610	$3,387,938
	Maintenance Cost Savings	$62,672	$124,418
	Residual Value of Assets	$3,939,096	$15,526,459
Total Benefit Estimates		**$366,489,042**	**$754,466,710**

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 1.39 (National) leads to a $28.8 million increase in the project NPV. Changing the value of travel time for all motorists to 25% above/below values recommended by USDOT results in a change of +$25.1 million to -$25.1 million in the NPV and a BCR of 1.38 to 0.77. Changes in the capital cost estimates of the project have similar impacts on the results and tend to have more impact on the BCR which is highly sensitive to the project costs. Overall, the benefit-cost ratio close to one for each of the sensitivity analyses presented below suggests that the project is a worthwhile investment from a societal standpoint.

Table 18: 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	+25% Increase in Values Recommended by US DOT	$6,533,195	$31,643,986	384.36%	1.38
	-25% Decrease in Values Recommended by US DOT		($18,577,596)	(384.36%)	0.77
Average Vehicle Occupancy (AVO)	National Average instead of Oklahoma AVO*		$35,364,103	441.30%	1.43
Capital Cost Estimate	25% Increase		($14,041,815)	(314.93%)	0.86
	25% Reduction		$27,108,205	314.93%	1.44

*National Average is 1.39, Source: Federal Highway Administration Highway Statistics 2015, Table VM1

10 Supplementary Data Tables

This section breaks down all benefits associated with the “Support for National and Regional Economic Vitality” merit criteria (broken out into Economic, Safety, and Emission Benefits) in annual form for the I-44 Corridor 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 emissions avoided are included.

Table 19: Annual Monetized Estimates of Total Project Benefits and Costs

Calendar Year	Project Year	Total Benefits $2016	Total Costs $2016	Undiscounted Net Benefits ($2016)	Discounted Net Benefit at 7%	Discounted Net Benefit at 3%
2016	1	$0	$1,162,903	($1,162,903)	($1,162,903)	($1,162,903)
2017	2	$0	$1,093,864	($1,093,864)	($1,022,303)	($1,062,004)
2018	3	$0	$1,077,354	($1,077,354)	($941,003)	($1,015,509)
2019	4	$0	$18,387,834	($18,387,834)	($15,009,950)	($16,827,473)
2020	5	$0	$46,176,666	($46,176,666)	($35,227,957)	($41,027,370)
2021	6	$0	$22,186,000	($22,186,000)	($15,818,311)	($19,137,838)
2022	7	$0	$19,686,000	($19,686,000)	($13,117,613)	($16,486,715)
2023 (opening)	8	$9,897,541	$0	$9,897,541	$6,163,691	$8,047,607
2024	9	$10,064,815	$0	$10,064,815	$5,857,814	$7,945,258
2025	10	$10,142,442	$0	$10,142,442	$5,516,816	$7,773,337
2026	11	$9,957,802	$0	$9,957,802	$5,062,041	$7,409,540
2027	12	$10,132,768	$0	$10,132,768	$4,814,005	$7,320,127
2028	13	$10,548,690	$0	$10,548,690	$4,683,745	$7,398,639
2029	14	$10,524,979	$0	$10,524,979	$4,367,492	$7,166,999
2030	15	$10,415,233	$0	$10,415,233	$4,039,207	$6,885,696
2031	16	$10,629,755	$0	$10,629,755	$3,852,712	$6,822,835
2032	17	$10,307,720	$0	$10,307,720	$3,491,581	$6,423,430
2033	18	$10,441,808	$0	$10,441,808	$3,305,609	$6,317,466
2034	19	$10,531,011	$0	$10,531,011	$3,115,746	$6,185,859
2035	20	$10,427,560	$0	$10,427,560	$2,883,307	$5,946,692
2036	21	$10,407,067	$0	$10,407,067	$2,689,384	$5,762,141
2037	22	$10,386,574	$0	$10,386,574	$2,508,494	$5,583,295
2038	23	$10,366,081	$0	$10,366,081	$2,339,761	$5,409,980
2039	24	$10,345,588	$0	$10,345,588	$2,182,370	$5,242,024
2040	25	$10,325,095	$0	$10,325,095	$2,035,558	$5,079,263
2041	26	$10,304,602	$0	$10,304,602	$1,898,615	$4,921,535
2042	27	$10,284,109	$0	$10,284,109	$1,770,877	$4,768,687
2043	28	$10,263,616	$0	$10,263,616	$1,651,728	$4,620,568
2044	29	$10,243,124	$0	$10,243,124	$1,540,588	$4,477,031
2045	30	$10,222,631	$0	$10,222,631	$1,436,922	$4,337,936
2046	31	$10,202,138	$0	$10,202,138	$1,340,225	$4,203,146
2047	32	$10,181,645	$0	$10,181,645	$1,250,031	$4,072,527
2048	33	$10,161,152	$0	$10,161,152	$1,165,902	$3,945,952
2049	34	$10,140,659	$0	$10,140,659	$1,087,430	$3,823,295
2050	35	$10,120,166	$0	$10,120,166	$1,014,236	$3,704,435
2051	36	$10,099,673	$0	$10,099,673	$945,965	$3,589,256
2052	37	$55,079,180	$0	$55,079,180	$4,821,381	$19,004,103
Total		**$353,155,225**	**$109,770,621**	**$243,384,604**	**$6,533,195**	**$87,468,846**

Table 20: 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	655,267,597	677,850,394	16,183,246	15,459,611	40.5	43.8
2024	9	652,416,641	674,901,184	16,129,096	15,407,882	40.4	43.8
2025	10	649,565,684	671,951,974	16,074,945	15,356,152	40.4	43.8
2026	11	646,714,728	669,002,764	16,020,794	15,304,423	40.4	43.7
2027	12	643,863,772	666,053,554	15,966,643	15,252,693	40.3	43.7
2028	13	641,012,816	663,104,344	15,912,492	15,200,964	40.3	43.6
2029	14	638,161,860	660,155,134	15,858,341	15,149,234	40.2	43.6
2030	15	635,310,903	657,205,924	15,804,190	15,097,505	40.2	43.5
2031	16	632,459,947	654,256,714	15,750,040	15,045,775	40.2	43.5
2032	17	629,608,991	651,307,504	15,695,889	14,994,046	40.1	43.4
2033	18	626,758,035	648,358,293	15,641,738	14,942,316	40.1	43.4
2034	19	623,907,078	645,409,083	15,587,587	14,890,587	40.0	43.3
2035	20	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2036	21	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2037	22	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2038	23	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2039	24	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2040	25	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2041	26	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2042	27	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2043	28	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2044	29	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2045	30	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2046	31	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2047	32	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2048	33	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2049	34	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2050	35	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2051	36	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
2052	37	621,056,122	642,459,873	15,533,436	14,838,857	40.0	43.3
Total		**18,854,058,251**	**19,503,834,586**	**470,226,853**	**449,200,624**		

Table 21: Annual Average Travel Time (Hours)

Calendar Year	Project Year	No-Build	Build	Total Person-Hours of Time Saved
2023 (opening)	8	1,248,422	1,192,599	55,823
2024	9	1,244,245	1,188,608	55,636
2025	10	1,240,067	1,184,617	55,450
2026	11	1,235,890	1,180,627	55,263
2027	12	1,231,712	1,176,636	55,076
2028	13	1,227,535	1,172,646	54,889
2029	14	1,223,358	1,168,655	54,703
2030	15	1,219,180	1,164,665	54,516
2031	16	1,215,003	1,160,674	54,329
2032	17	1,210,826	1,156,684	54,142
2033	18	1,206,648	1,152,693	53,955
2034	19	1,202,471	1,148,702	53,769
2035	20	1,198,294	1,144,712	53,582
2036	21	1,198,294	1,144,712	53,582
2037	22	1,198,294	1,144,712	53,582
2038	23	1,198,294	1,144,712	53,582
2039	24	1,198,294	1,144,712	53,582
2040	25	1,198,294	1,144,712	53,582
2041	26	1,198,294	1,144,712	53,582
2042	27	1,198,294	1,144,712	53,582
2043	28	1,198,294	1,144,712	53,582
2044	29	1,198,294	1,144,712	53,582
2045	30	1,198,294	1,144,712	53,582
2046	31	1,198,294	1,144,712	53,582
2047	32	1,198,294	1,144,712	53,582
2048	33	1,198,294	1,144,712	53,582
2049	34	1,198,294	1,144,712	53,582
2050	35	1,198,294	1,144,712	53,582
2051	36	1,198,294	1,144,712	53,582
2052	37	1,198,294	1,144,712	53,582
Total		**36,274,643**	**34,652,620**	**1,622,023**

Table 22: Economic - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits $2016	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	$5,196,846	$3,236,334	$4,225,511
2024	9	$5,325,661	$3,099,583	$4,204,126
2025	10	$5,413,921	$2,944,814	$4,149,320
2026	11	$5,276,331	$2,682,219	$3,926,086
2027	12	$5,445,280	$2,587,013	$3,933,786
2028	13	$5,829,526	$2,588,379	$4,088,712
2029	14	$5,821,258	$2,415,615	$3,963,994
2030	15	$5,832,484	$2,261,938	$3,855,959
2031	16	$6,064,868	$2,198,187	$3,892,808
2032	17	$5,775,385	$1,956,323	$3,599,029
2033	18	$5,926,010	$1,876,023	$3,585,333
2034	19	$6,033,735	$1,785,164	$3,544,183
2035	20	$5,958,881	$1,647,680	$3,398,266
2036	21	$5,958,881	$1,539,888	$3,299,288
2037	22	$5,958,881	$1,439,148	$3,203,192
2038	23	$5,958,881	$1,344,998	$3,109,895
2039	24	$5,958,881	$1,257,007	$3,019,316
2040	25	$5,958,881	$1,174,773	$2,931,374
2041	26	$5,958,881	$1,097,919	$2,845,995
2042	27	$5,958,881	$1,026,092	$2,763,102
2043	28	$5,958,881	$958,965	$2,682,623
2044	29	$5,958,881	$896,229	$2,604,488
2045	30	$5,958,881	$837,597	$2,528,629
2046	31	$5,958,881	$782,801	$2,454,980
2047	32	$5,958,881	$731,590	$2,383,476
2048	33	$5,958,881	$683,729	$2,314,054
2049	34	$5,958,881	$638,999	$2,246,654
2050	35	$5,958,881	$597,195	$2,181,218
2051	36	$5,958,881	$558,126	$2,117,687
2052	37	$50,958,881	$4,460,709	$17,582,466
Total		**$220,201,157**	**$51,305,038**	**$110,635,551**

Table 23: Safety – Pertinent Quantifiable Impacts

Calendar Year	Project Year	Fatalities Avoided	Injuries Avoided	PDO Avoided
2023 (opening)	8	0.39	8.28	13.09
2024	9	0.39	8.25	13.03
2025	10	0.39	8.21	12.97
2026	11	0.38	8.17	12.92
2027	12	0.38	8.14	12.86
2028	13	0.38	8.10	12.80
2029	14	0.38	8.06	12.74
2030	15	0.38	8.03	12.69
2031	16	0.38	7.99	12.63
2032	17	0.37	7.96	12.57
2033	18	0.37	7.92	12.52
2034	19	0.37	7.88	12.46
2035	20	0.37	7.85	12.40
2036	21	0.37	7.81	12.35
2037	22	0.37	7.78	12.29
2038	23	0.36	7.74	12.23
2039	24	0.36	7.70	12.18
2040	25	0.36	7.67	12.12
2041	26	0.36	7.63	12.06
2042	27	0.36	7.60	12.00
2043	28	0.36	7.56	11.95
2044	29	0.35	7.52	11.89
2045	30	0.35	7.49	11.83
2046	31	0.35	7.45	11.78
2047	32	0.35	7.42	11.72
2048	33	0.35	7.38	11.66
2049	34	0.35	7.34	11.61
2050	35	0.34	7.31	11.55
2051	36	0.34	7.27	11.49
2052	37	0.34	7.24	11.44
Total		**10.94**	**232.76**	**367.82**

Table 24: Safety - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits 2016 Dollars	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	$4,710,129	$2,933,231	$3,829,766
2024	9	$4,689,636	$2,729,411	$3,702,042
2025	10	$4,669,143	$2,539,704	$3,578,509
2026	11	$4,648,650	$2,363,138	$3,459,032
2027	12	$4,628,157	$2,198,804	$3,343,479
2028	13	$4,607,664	$2,045,858	$3,231,723
2029	14	$4,587,171	$1,903,513	$3,123,640
2030	15	$4,566,678	$1,771,036	$3,019,112
2031	16	$4,546,185	$1,647,747	$2,918,023
2032	17	$4,525,692	$1,533,008	$2,820,262
2033	18	$4,505,199	$1,426,231	$2,725,719
2034	19	$4,484,706	$1,326,863	$2,634,292
2035	20	$4,464,213	$1,234,392	$2,545,878
2036	21	$4,443,720	$1,148,342	$2,460,380
2037	22	$4,423,227	$1,068,267	$2,377,703
2038	23	$4,402,734	$993,755	$2,297,754
2039	24	$4,382,241	$924,420	$2,220,445
2040	25	$4,361,748	$859,904	$2,145,691
2041	26	$4,341,255	$799,873	$2,073,408
2042	27	$4,320,762	$744,016	$2,003,515
2043	28	$4,300,269	$692,044	$1,935,934
2044	29	$4,279,776	$643,688	$1,870,591
2045	30	$4,259,284	$598,697	$1,807,411
2046	31	$4,238,791	$556,838	$1,746,326
2047	32	$4,218,298	$517,893	$1,687,265
2048	33	$4,197,805	$481,661	$1,630,163
2049	34	$4,177,312	$447,953	$1,574,956
2050	35	$4,156,819	$416,594	$1,521,582
2051	36	$4,136,326	$387,420	$1,469,982
2052	37	$4,115,833	$360,281	$1,420,096
Total		**$132,389,421**	**$37,294,581**	**$73,174,678**

Table 25: Annual Emissions Saved

Calendar Year	Project Year	Annual CO2 Emissions Saved (Short Tons)[3]	Annual NOx Emissions Saved (Grams)	Annual PM Emissions Saved (Grams)	Annual SOx Emissions Saved (Grams)	Annual VOC Emissions Saved (Grams)
2023 (opening)	8	(1,638)	(4,945,515)	81,222	(20,886)	762,671
2024	9	(823)	(3,174,774)	198,220	(6,243)	921,058
2025	10	(582)	(2,537,955)	210,472	(7,431)	1,008,269
2026	11	(998)	(3,079,073)	153,984	(22,386)	802,509
2027	12	(473)	(1,984,977)	199,179	(11,525)	937,595
2028	13	788	85,057	289,739	4,191	1,370,620
2029	14	922	176,567	299,865	15,245	1,374,261
2030	15	1,041	859,664	23,387	2,576	124,395
2031	16	1,325	1,011,139	27,031	2,871	138,728
2032	17	(73)	332,751	10,463	(3,588)	105,358
2033	18	451	578,966	15,244	(541)	119,508
2034	19	684	716,323	17,372	396	127,847
2035	20	19	341,421	4,146	(1,858)	114,838
2036	21	19	341,421	4,146	(1,858)	114,838
2037	22	19	341,421	4,146	(1,858)	114,838
2038	23	19	341,421	4,146	(1,858)	114,838
2039	24	19	341,421	4,146	(1,858)	114,838
2040	25	19	341,421	4,146	(1,858)	114,838
2041	26	19	341,421	4,146	(1,858)	114,838
2042	27	19	341,421	4,146	(1,858)	114,838
2043	28	19	341,421	4,146	(1,858)	114,838
2044	29	19	341,421	4,146	(1,858)	114,838
2045	30	19	341,421	4,146	(1,858)	114,838
2046	31	19	341,421	4,146	(1,858)	114,838
2047	32	19	341,421	4,146	(1,858)	114,838
2048	33	19	341,421	4,146	(1,858)	114,838
2049	34	19	341,421	4,146	(1,858)	114,838
2050	35	19	341,421	4,146	(1,858)	114,838
2051	36	19	341,421	4,146	(1,858)	114,838
2052	37	19	341,421	4,146	(1,858)	114,838
Total		**964**	**(5,816,252)**	**1,600,802**	**(80,765)**	**9,859,908**

[3] CO_2 values were not monetized in this analysis.

Table 26: Emissions - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits $2016	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	($9,433)	($5,875)	($7,670)
2024	9	$49,519	$28,820	$39,090
2025	10	$59,378	$32,298	$45,508
2026	11	$32,821	$16,685	$24,422
2027	12	$59,331	$28,188	$42,862
2028	13	$111,501	$49,508	$78,204
2029	14	$116,550	$48,364	$79,365
2030	15	$16,071	$6,233	$10,625
2031	16	$18,702	$6,778	$12,004
2032	17	$6,643	$2,250	$4,140
2033	18	$10,599	$3,356	$6,413
2034	19	$12,570	$3,719	$7,384
2035	20	$4,466	$1,235	$2,547
2036	21	$4,466	$1,154	$2,473
2037	22	$4,466	$1,079	$2,401
2038	23	$4,466	$1,008	$2,331
2039	24	$4,466	$942	$2,263
2040	25	$4,466	$881	$2,197
2041	26	$4,466	$823	$2,133
2042	27	$4,466	$769	$2,071
2043	28	$4,466	$719	$2,011
2044	29	$4,466	$672	$1,952
2045	30	$4,466	$628	$1,895
2046	31	$4,466	$587	$1,840
2047	32	$4,466	$548	$1,786
2048	33	$4,466	$512	$1,734
2049	34	$4,466	$479	$1,684
2050	35	$4,466	$448	$1,635
2051	36	$4,466	$418	$1,587
2052	37	$4,466	$391	$1,541
Total		**$564,647**	**$233,616**	**$378,430**

Table 27: Travel Time - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits $2016	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	$12,452,833	$7,754,999	$10,125,293
2024	9	$12,411,165	$7,223,411	$9,797,488
2025	10	$12,369,496	$6,728,186	$9,480,189
2026	11	$12,327,828	$6,266,843	$9,173,062
2027	12	$12,286,159	$5,837,066	$8,875,783
2028	13	$12,244,491	$5,436,700	$8,588,040
2029	14	$12,202,822	$5,063,737	$8,309,528
2030	15	$12,161,154	$4,716,305	$8,039,955
2031	16	$12,119,485	$4,392,659	$7,779,037
2032	17	$12,077,817	$4,091,174	$7,526,496
2033	18	$12,036,148	$3,810,336	$7,282,068
2034	19	$11,994,480	$3,548,734	$7,045,493
2035	20	$11,952,811	$3,305,052	$6,816,521
2036	21	$11,952,811	$3,088,834	$6,617,982
2037	22	$11,952,811	$2,886,760	$6,425,225
2038	23	$11,952,811	$2,697,907	$6,238,083
2039	24	$11,952,811	$2,521,408	$6,056,391
2040	25	$11,952,811	$2,356,456	$5,879,991
2041	26	$11,952,811	$2,202,296	$5,708,729
2042	27	$11,952,811	$2,058,220	$5,542,456
2043	28	$11,952,811	$1,923,570	$5,381,025
2044	29	$11,952,811	$1,797,729	$5,224,296
2045	30	$11,952,811	$1,680,121	$5,072,132
2046	31	$11,952,811	$1,570,206	$4,924,400
2047	32	$11,952,811	$1,467,483	$4,780,971
2048	33	$11,952,811	$1,371,479	$4,641,719
2049	34	$11,952,811	$1,281,756	$4,506,524
2050	35	$11,952,811	$1,197,903	$4,375,266
2051	36	$11,952,811	$1,119,535	$4,247,831
2052	37	$11,952,811	$1,046,295	$4,124,108
Total		**$361,834,486**	**$100,443,163**	**$198,586,081**

Table 28: Vehicle Operating Costs - Annual Benefit Estimates

Calendar Year	Project Year	Total Benefits $2016	Discounted Benefits at 7%	Discounted Benefits at 3%
2023 (opening)	8	($7,263,567)	($4,523,385)	($5,905,945)
2024	9	($7,093,084)	($4,128,239)	($5,599,346)
2025	10	($6,963,155)	($3,787,495)	($5,336,678)
2026	11	($7,059,077)	($3,588,477)	($5,252,616)
2027	12	($6,848,459)	($3,253,654)	($4,947,473)
2028	13	($6,422,545)	($2,851,687)	($4,504,643)
2029	14	($6,389,144)	($2,651,267)	($4,350,696)
2030	15	($6,336,249)	($2,457,307)	($4,189,007)
2031	16	($6,062,197)	($2,197,219)	($3,891,094)
2032	17	($6,310,011)	($2,137,419)	($3,932,191)
2033	18	($6,117,718)	($1,936,713)	($3,701,320)
2034	19	($5,968,324)	($1,765,812)	($3,505,762)
2035	20	($6,001,510)	($1,659,468)	($3,422,577)
2036	21	($6,001,510)	($1,550,904)	($3,322,891)
2037	22	($6,001,510)	($1,449,443)	($3,226,107)
2038	23	($6,001,510)	($1,354,620)	($3,132,143)
2039	24	($6,001,510)	($1,266,000)	($3,040,916)
2040	25	($6,001,510)	($1,183,177)	($2,952,345)
2041	26	($6,001,510)	($1,105,773)	($2,866,355)
2042	27	($6,001,510)	($1,033,433)	($2,782,869)
2043	28	($6,001,510)	($965,825)	($2,701,814)
2044	29	($6,001,510)	($902,640)	($2,623,121)
2045	30	($6,001,510)	($843,589)	($2,546,719)
2046	31	($6,001,510)	($788,401)	($2,472,543)
2047	32	($6,001,510)	($736,823)	($2,400,527)
2048	33	($6,001,510)	($688,620)	($2,330,609)
2049	34	($6,001,510)	($643,570)	($2,262,727)
2050	35	($6,001,510)	($601,467)	($2,196,822)
2051	36	($6,001,510)	($562,119)	($2,132,837)
2052	37	($6,001,510)	($525,345)	($2,070,716)
Total		**($186,860,714)**	**($53,139,892)**	**($103,601,407)**