Priority Improvements on the I-35 Corridor

Benefit-Cost Analysis Supplementary Documentation for MDGP INFRA Grant Program

Oklahoma Department of Transportation

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Benefit-Cost Analysis Supplementary Documentation

1 Executive Summary

The benefit-cost analysis (BCA) 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. A qualitative discussion is also provided when a benefit is anticipated to be generated but is not easily monetized or quantified.

The project for which this Multimodal Project Discretionary Grant (MPDG) grant is requested, the I-35 Corridor Priority Improvements (the Project), is located along the Interstate 35 (I-35) from Mile Marker 3 in Love County to Mile Marker 108 in McClain County, Oklahoma. The Project prioritizes approximately 13 miles of this corridor for widening (addition of one lane in each direction of travel) and interchange reconstructions at SH-9W and SH-153. The first prioritized segment, South Segment, is in Love County from Mile Marker 3 (Rogers Road) to Mile Marker 8 (US-77). The second prioritization segment, North Segment, is in McClain County from Mile Marker 100 (Ladd Road) to Mile Marker 108 (SH-9W).

I-35 is the only continuous north-south interstate that provides connection to Kansas and Texas. It serves as the backbone of the state's economy, moving people to work and goods to market while connecting Oklahoma with the nation and the world.

The I-35 project corridor does not currently provide adequate mobility for the over 63,000 cars and trucks (with 20 percent truck share) that use it each day in the project area. By 2050, daily traffic is expected to exceed 100,000 vehicles per day. Without improvement, Level of Service (LOS) F conditions are projected for priority segments as early as 2030 with increasing delays through 2050. The expected delays will increase travel time and reduce reliability for the important freight traffic. This severe congestion will also result in additional vehicle emissions and secondary accidents.

With the proposed lane additions and the upgraded interchanges at SH-9W and SH-153, the project would provide additional capacity to accommodate current and future traffic demand. With the lane widening, the priority segments LOS rating would be improved by one letter grade under existing and future conditions and interchange improvements at SH-9W would significantly reduce interchange travel time. The additional capacity and a wider inside shoulder would also improve reliability and help reduce the number of collisions.

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

Table ES-1: Summary of Infrastructure Improvements and Associated Benefits

Current Status (Base Scenario) & Problems to be Addressed	Changes to Baseline (Alternative Scenario)	Merit Criteria	Economic Benefits	Types of Impact	Estimated Value, $M (7% Discount Rate
I-35 serves as the backbone of the state's economy, moving people to work and goods to market while connecting Oklahoma to the nation and the world. The I-35 project corridor does not currently provide adequate mobility for the over 63,000 cars and trucks that use it each day in the project area, and by 2050 traffic is expected to increase to 100,000 vehicles per day. Without improvement, LOS F conditions are projected for priority segments as early as 2030. The expected delays increase travel time and reduce reliability for the important freight traffic. This severe congestion will also result in additional vehicle emissions and secondary accidents.	With the proposed lane additions and the new interchanges at SH-9W and SH-153, the project would provide additional capacity to accommodate current and future traffic demand. With the lane widening, the priority segments LOS would be improved by one letter grade and interchange improvements at SH-9W would significantly reduce interchange travel delays. The additional capacity and a wider inside shoulder would provide better reliability and help reduce the number of collisions. The additional capacity from the lane additions would also reduce travel times and improve LOS rating.	Economic Competitiveness	Travel Time Savings	Improved travel times from increased speeds as a result of lane additions.	**$34.5**
				Improved travel time from reducing delays experienced at interchanges during peak hours.	**$273.0**
		Safety	Improved Safety	Improved roadway safety from increasing the number of lanes.	**$32.7**
		Environmental Sustainability	Reduced Emissions	Avoided emissions from reduced delays and idling times at the SH-9W and SH-153 interchanges.	**$2.2**
		State of Good Repair	Incremental O&M Costs	Reduced O&M from reconstructing infrastructure.	**$1.9**
			Residual Value of Assets	Residual value of capital assets.	**$12.9**

The period of analysis used in the monetization of benefits and costs is 23 years, including three years of development and construction and 20 years of operation. Total project construction costs are estimated at $139.6 million in 2022 dollars and $128.4 million in 2020 dollars.

All relevant data and calculations used to derive the benefits and costs of the project are shown in the BCA model that accompanies this grant application. Based on the analysis presented in the rest of this document, the Project is expected to generate $357.1 million in discounted benefits, and $100.3 million in discounted capital costs, using a 7 percent real discount rate. Therefore, the Project is expected to generate a Net Present Value of $256.8 million and a Benefit/Cost Ratio of 3.6 as shown below in Table ES- 2.

Table ES-2: Summary of BCA Outcomes

Evaluation Metrics	Undiscounted	Discounted
Total Benefits	$1,121.9	$357.1
Total Costs	$128.4	$100.3
Net Present Value (NPV)	$993.5	$256.8
Benefit-Cost Ratio (BCR)	8.7	3.6
Payback Period (years)	10.3 years	11.7 years
Return on Investment (ROI)	773%	256%
Internal Rate of Return (IRR)	21.2%	

In addition to the monetized benefits presented in Table ES-1 and captured in the project evaluation metrics shown in Table ES-2, the Project would generate benefits that are difficult to quantify and monetize, but they can be considered as qualitative benefits of the project. These benefits are briefly outlined below.

- Improvement in reliability of travel. With the reduction in the average travel times on the mainline and delays at interchanges, vehicle flow and reliability of travel times can be expected to improve, significantly as well benefitting personal travel and commercial freight traffic in this corridor.
- Support of other priority planning areas. Improvements in the priority segments would support the turnpike planning effort that would provide connections between I-35 and I-40 outside of Oklahoma City (Advancing and Connecting Communities and Economies Safely Statewide (ACCESS Oklahoma)).
- Support of development of renewable energy sector in Oklahoma. The state also produces a significant amount of wind energy, and the sector growth is expected to continue. The I-35 freight corridor would be key to serving the manufacturing, construction, servicing, and transportation of turbine components which are logistically quite complex.

2 Methodological Framework

The BCA conducted for this project includes the monetized benefits and costs measured using USDOT guidance, as well as the quantitative and qualitative merits of the project. A BCA provides estimates of the benefits that are expected to accrue from a project over a specified period and compares them to the anticipated costs of the project. Costs include both the resources required to develop the project and the costs of maintaining the new or improved asset over time. Estimated benefits are based on the projected impacts of the project on both users and non-users of the facility, valued in monetary terms.[1]

While a BCA is just one of many tools that can be used in making decisions about infrastructure investments, USDOT believes that it provides a useful benchmark from which to evaluate and compare potential transportation investments.[2]

The specific methodology adopted for this application is based on the BCA guidance developed by USDOT and is consistent with the INFRA program guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the Build and No-Build scenarios;
- Assessing benefits with respect to project requirements listed in NOFO;
- 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, and safety benefits, while relying on industry best practices for the valuation of other effects;
- Discounting future benefits and costs with the real discount rate recommended by USDOT (7 percent, except for carbon dioxide which is discounted at 3 percent); and,
- Conducting a sensitivity analysis to assess the impacts of changes in key input assumptions.

3 Project Overview

The project encompasses Interstate 35 (I-35) from Mile Marker 3 in Love County to Mile Marker 108 in McClain County and prioritizes approximately 13 miles of this corridor for widening (addition of one lane in each direction of travel) and interchange reconstruction at SH-9W and SH-153. These areas are highlighted in Figure 1. The first prioritized segment, South Segment, is in Love County from Mile Marker 3 (Rogers Road) to Mile Marker 8 (US-77). The second prioritization segment, North Segment, is in McClain County from Mile Marker 100 (Ladd Road) to Mile Marker 108 (SH-9W).

The priority segments were identified based on the surface condition, average annual daily traffic (AADT), percentage of truck traffic, collision history, local, regional, and national traffic patterns, and capacity. The Northern Segment is also identified in the

[1] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, March 2022 Revised.
[2] Ibid.

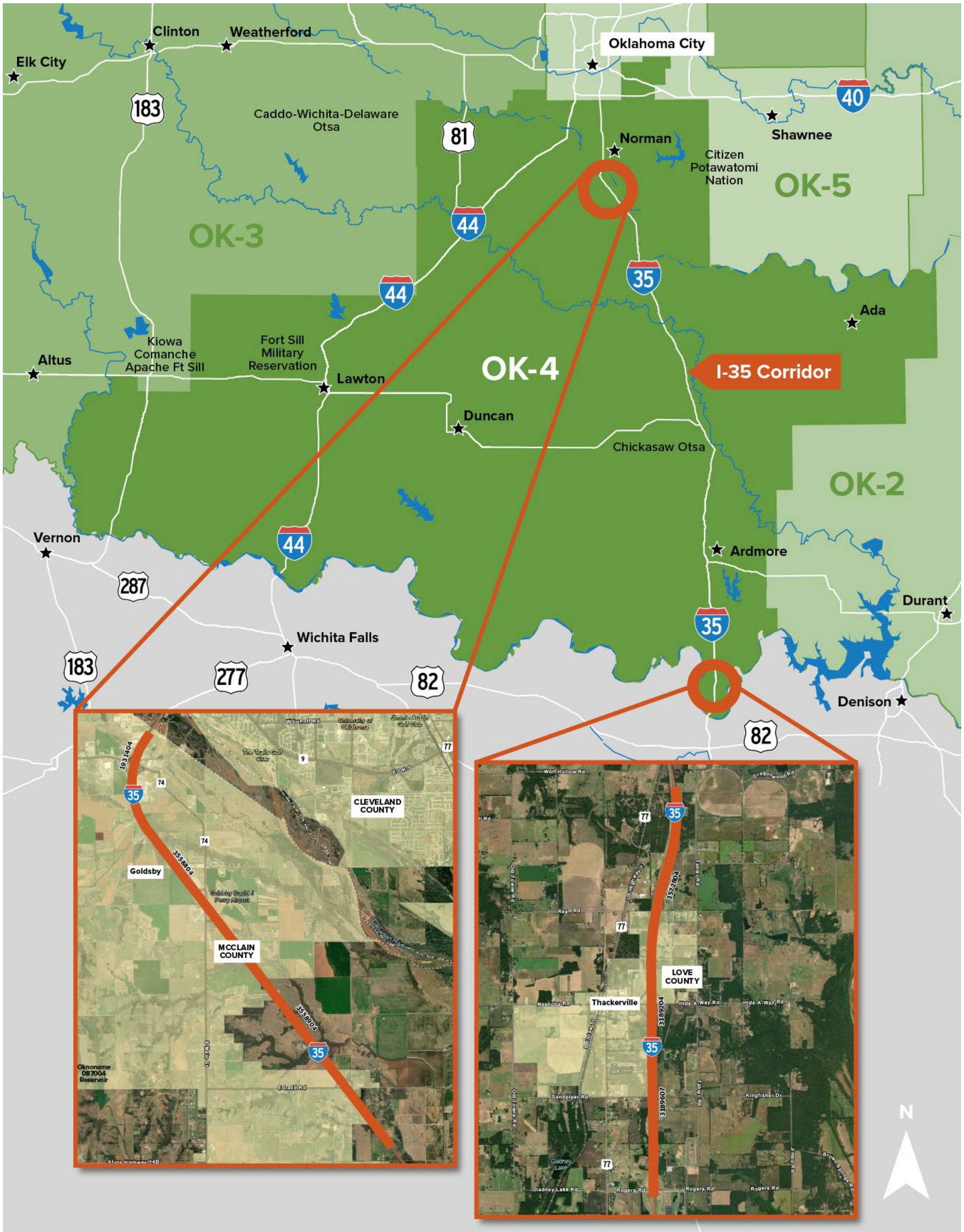
Statewide Transportation (STIP) Improvement Program for Fiscal Year 2022 and in the Oklahoma Freight Transportation Plan as a top-ranked highway freight mobility project (FY 2018-2022) and to pursue investment funds from federal or state sources.

I-35 is the only continuous north-south interstate that provides connection to Kansas and Texas. It serves as the backbone of the state's economy, moving people to work and goods to market while connecting Oklahoma with the nation and the world.

The I-35 project corridor does not currently provide adequate mobility for the over 63,000 cars and trucks (with 20 percent truck share) that use it each day in the project area. By 2050, daily traffic is expected to exceed 100,000 vehicles per day. Without improvement, LOS F conditions are projected for priority segments as early as 2030 with increasing delays through 2050. The expected delays will increase travel time and reduce reliability for the important freight traffic. This severe congestion will also result in additional vehicle emissions and secondary accidents.

With the proposed lane addition and the upgraded interchanges at SH-9W and SH-153, the project would provide additional capacity to accommodate current and future traffic demand. With the lane widening, the priority segments LOS rating would be improved by one letter grade under existing and future conditions and interchange improvements at SH-9W would significantly reduce interchange travel time. The additional capacity and a wider inside shoulder would also improve reliability and help reduce the number of collisions.

Figure 1. Locations for I-35 Corridor Priority Improvements



4 Base Case and Alternative

The Base Case for the I-35 Corridor Priority Improvement projects is defined as the "No-Build" scenario. The No-Build scenario reflects the continuation of current conditions with no major investments to address the identified challenges related to the project areas. The Alternative Case is defined as the Build scenario that includes all project components with their associated impacts, listed in Section 4.1 below.

4.1 Types of Impacts

The proposed project is expected to have the following impacts:

- Improved travel times from increased speeds as a result of lane additions;
- Improved travel time from reducing delays experienced at interchanges during peak hours;
- Improve roadway safety from increasing the number of lanes;
- Avoided emissions from reduced idling times at the SH-9W and SH-153 interchanges;
- Reduced O&M due to reconstructing infrastructure and improving "state of good repair"; and,
- The residual value of capital assets.

4.2 Project Cost and Schedule

Total project capital construction costs are estimated at 139.6 million in 2022 dollars. For this BCA, costs were de-escalated to 2020 dollars using the GDP deflator. The adjusted cost in 2020 dollars amounted then to $128.4 million[3]. A portion of these costs, listed under 2021 and 2022 are previously incurred costs. Project construction is anticipated to start in 2023 and finish in 2025 as shown in the table below. At the 7 percent discount rate, total construction costs are estimated at $100.3 million.

Table 1. Capital Costs by Year (Millions of 2020 Dollars)

Year	Undiscounted	Discounted
2021	$7.9	$7.4
2022	$7.9	$6.9

[3] Unless stated otherwise, all dollar values in this report are measured in real 2020 dollars. Values expressed in dollars of another year were converted to 2020 dollars. Deflation adjustments were applied using the GDP deflators from the Bureau of Economic Analysis, National Income and Product Accounts, Table 1.1.9, "Implicit Price Deflators for Gross Domestic Product" (April 2022).

2023	$37.6	$30.7
2024	$37.6	$28.7
2025	$37.6	$26.8
Total	$128.4	$100.3

4.3 Alignment with Project Requirements

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

Table 2. Benefit Categories and Expected Alignment with Project Requirements

Merit Criteria	Benefit Category	Description	Monetized	Qualitative
Economic Competitiveness	Travel Time Savings	Improved travel times from increased speeds as a result of lane additions.	Yes	-
		Improved travel time from reducing delays experienced at interchanges during peak hours.	Yes	-
Safety	Improved Safety	Improved roadway safety from increasing the number of lanes.	Yes	-
Environmental Sustainability	Reduced Emissions	Avoided emissions from reduced delays and thus idling times at the SH-9W and SH-153 interchanges.	Yes	-
State of Good Repair	Incremental O&M Costs	Reduced O&M from reconstructing infrastructure achieving state of good repair	Yes	-
	Residual Value of Assets	Residual value of capital assets.	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 methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices, costs, and benefits are expressed in 2020 dollars;
- The period of analysis begins in 2021 and ends in 2045. It includes previously conducted project development activities (2021 – 2022), construction years (2023 – 2025), and 20 years of operations (2026 – 2045);
- A constant 7 percent real discount rate is assumed throughout the period of analysis, with the exception of benefits and costs related to carbon dioxide emissions which are discounted at a 3 percent rate; and,
- Opening year demand and benefits are inputs to the BCA and are assumed to be fully realized after construction is finished and project starts operations in 2026 (no ramp-up).

6 Demand and Other Key Inputs Projections

Accurate demand projections are important to effectively estimate the benefits in a BCA. Other key inputs in the estimation of benefits include average speeds, delays, vehicle miles of travel, distribution of traffic over the course of the day. This section discusses data sources and methodology, and presents the resulting projections.

6.1 Methodology

The demand projections discussed in this section are for the Build and No-Build vehicle-miles travelled (VMT), separated into four sets of projections based on the four priority improvements. The change in vehicle-miles travelled between the Build and No-Build scenarios drive the estimated benefits from travel time savings and emissions reductions. This change is not dependent on changes in AADT, which is assumed to remain the same between the scenarios.

Two separate methodologies are employed to account for the differences between the benefits derived from increasing the number of lanes and the benefits derived from redesigning the interchanges. Table 3 provides an overview of these methodologies.

Table 3. Priority Improvements along the I-35 Corridor[4]

Name	Description	Methodology
I-35 (N)	Increasing the number of lanes from 4 to 6	Benefits are derived from increased driving speeds from the increase in lanes.
I-35 (S)	Increasing the number of lanes from 4 to 6	
SH-9W	Redesign interchange	Benefits are derived from reducing the delays per vehicle during peak-hour periods at the interchange.
SH-153	Redesign interchange	

6.1.1 Lane Additions

For the lane additions, VMT is calculated using the assumptions on average annual daily traffic (AADT), length, and speed. Using the estimated AADT in 2022 and in 2052, values for the years in-between were interpolated using a compounded annual growth rate. Due to the nature of the project, AADT is not expected to increase between Build and No-Build scenarios.

Speed projections over the study period were interpolated from 2022 and 2045 estimates, broken down by Build versus No-Build speeds and peak period versus non-peak period speeds. The average daily speeds in 2022, listed in Table 4, were used for the 2022 No-Build speeds for both peak periods and non-peak periods.

To estimate speeds for 2045 and for the 2022 Build scenario, HDR followed the methodology from Equation 8-1 and Equation 8-7b of NCHRP Report 387[5]. Equation 8-1 defines the speed as

$$\text{Speed} = \frac{\text{Free-flow speed}}{1 + a\left(\frac{v}{c}\right)^{b}}$$

where v is the volume and c is the capacity; recommend parameters values are $a = 0.20$ for unsignalized facilities and $b = 10$. To account for differences in speeds over the course of a day, daily volume and daily capacity were split into peak and non-peak amounts. HDR used Equation 8-7b of NCHRP 387 to compute the capacity:

$$\text{Capacity (vph)} = \text{Ideal capacity } \times N \times F_{hv} \times PHF$$

For this equation, NCHRP 387 recommends using an ideal capacity of 2400 vehicle per hour per lane (vphpl) for freeways with 70 mph or greater free-flow speeds. The ideal capacity is then multiplied by the number of lanes N, the heavy vehicle adjustment factor F_{hv}, and the peak-hour factor PHF. The assumed free-flow speeds and capacity

[4] In the technical appendix and the accompanying Excel model, the four priority improvements are labelled using the names in Table 3.
[5] Dowling et al. (1997). NCHRP Report 387: Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications. Transportation Research Board National Research Council.

adjustment factors were provided by ODOT, and using the two formulas above, yielded the estimated 2022 and 2045 speeds used that were used for the calculation of VMT.

6.1.2 Interchange Redesign

The vehicle-miles travelled associated with the SH-9W interchange and the SH-153 interchange are hypothetical values that model the delays and idling times at the interchange during peak period hours for both the Build and No-Build scenarios. The VMT is calculated as the hours of delay divided by a proxy speed of 2.5 mph. This speed was chosen as it is the lowest speed listed in the emission factor data and thus provides an estimate for the tons of emissions emitted while idling at the interchange.

Table 4. Demand Projection Assumptions

Variable	Units	Value	Source
Peak Period Hours – AM	hours	2	Assumed
Peak Period Hours – PM	hours	2	
Number of Non-Peak Period Hours	hours	14	Assumed that volume is negligible for 6 hours each day (e.g., 12 AM to 6 AM). The remaining 18 hours minus the AM and PM peak period hours is the number of non-peak period hours.
Percent of Daily Travel during Peak Hours	%	32.8%	California DOT, Cal-B/C v8.1 Table: Demand for Travel during Peak Period (2021).
Percent of Daily Travel during Non-Peak Hours	%	67.2%	Assumed that the remaining volume outside the AM and PM peak periods are attributable to the 14 non-peak hours.

Table 5. Location-specific Demand Projection Assumptions

Variable	I-35 (N)	SH-9W	I-35 (S)	SH-153	Source
AADT (vehicles/day)					
2022	62,900	22,000	31,833	2,100	ODOT. Values for I-35 (N) and I-35 (S) represent averages of multiple traffic counts along both segments.
2052	100,500	35,000	50,933	3,500	
Speed (mph) and Capacity Adjustment Factors					
Free-Flow Speed	75.0		75.0		Assumed based on characteristics and

Variable	I-35 (N)	SH-9W	I-35 (S)	SH-153	Source
					classes of the roads; values are in line with posted speed limits.
2022 Average Observed Speed	72.0		72.7		Average of speed data provided by ODOT.
Heavy Vehicle Adjustment Factor (F_{hv})	0.910		0.914		Values from ODOT. Variables are defined as in Equation 8-7b of NCHRP 387.
Peak-Hour Factor (PHF)	0.900		0.900		
Delays (minutes/vehicle)					
2021 AM, No Build		0.5		0.0	SH-9W: Traffic estimates from ODOT. SH-153: Estimated using ratio of SH-9W volume to SH-153.
2021 AM, Build		0.4		0.0	
2050 AM, No Build		4.6		0.4	
2050 AM, Build		3.5		0.3	
2021 PM, No Build		1.5		0.1	
2021 PM, Build		0.4		0.0	
2050 PM, No Build		10.1		1.0	
2050 PM, Build		3.9		0.4	

6.2 Projections

The projected VMTs for the four priority improvements are shown in Table 6 along with the projected AADT, speeds, and delays used in the computations.

Table 6. Demand Projections by Location

Variable	I-35 (N)	SH-9W	I-35 (S)	SH-153	Comment
Volume (vehicles/year)					
2026	24,438,745	8,542,827	12,370,606	820,525	Values are interpolated using compounded annual growth.
2045	32,883,043	11,463,318	16,659,692	1,133,956	
Speed (mph)					

Variable	I-35 (N)	SH-9W	I-35 (S)	SH-153	Comment
2026 Peak, No Build	71.4		73.1		2022 Build and 2045 values estimated using methodology in NCHRP 387. 2026 values shown in this table are interpolated using compounded annual growth.
2026 Peak, Build	75.0		75.0		
2045 Peak, No Build	68.8		75.0		
2045 Peak, Build	74.9		75.0		
2026 Non-Peak, No Build	72.0		72.7		
2026 Non-Peak, Build	75.0		75.0		
2045 Non-Peak, No Build	72.0		72.7		
2045 Non-Peak, Build	75.0		75.0		
Delays (hours/vehicle)					
2026, No Build		0.09		0.01	Values are interpolated using compounded annual growth.
2026, Build		0.04		0.00	
2045, No Build		0.35		0.03	
2045, Build		0.17		0.02	
Vehicle Miles Travelled (vehicle-miles/year)					
2026, No Build	168,138,565	2,539,535	43,297,121	96,953	I-35 (N and S) are calculated using AADT, length, and speed. SH-9W and SH-153 are calculated using peak period delays and a proxy speed of 2.5 mph.
2026, Build	168,138,565	1,058,131	43,297,121	40,397	
2045, No Build	226,235,333	12,615,086	58,308,922	483,163	
2045, Build	226,235,333	6,111,046	58,308,922	234,056	

7 Benefits Measurement, Data and Assumptions

This section describes the measurement approaches and results for each quantifiable benefit or impact category identified in Table 2**.**

7.1 Economic Competitiveness

Economic competitiveness is monetized through two types of travel time savings: (1) reduced travel times from reduced speeds for I-35 (N) and I-35 (S), and (2) travel time improvements from reduced delays at SH-9W and SH-153.

7.1.1 Travel Time Savings

Travel time savings will accrue to motorists through faster speeds during both peak and non-peak periods of the day. The I-35 priority segments currently operate at LOS D and are expected to reach LOS F as early as 2030. With the lane additions, the additional capacity would improve the level of service by one letter grade. At the interchanges, delays are anticipated to be as high as 7.2 minutes per vehicle in 2045.

Methodology

Travel time savings are estimated by comparing the person-hours of travel time between the No-Build and Build cases. For lane additions, person-hours of travel time are calculated by multiplying the average vehicle occupancy by the VMT projections, then dividing by the speeds (from Table 6). To account for variations in speed by time of day, these calculations are split into peak and non-peak periods.

For interchange redesigns, the reduction in person-hours of travel time is estimated by multiplying the vehicle delay times and the peak period volumes.

Person-hours are monetized based on the percentage distribution of automobile drivers versus truck drivers and the associated value of travel time savings for each type of driver; this distribution varies by location.

Assumptions

The average vehicle occupancy, the value of time, and the peak period characteristics are listed in Table 7. Vehicle distributions by location are listed in Table 8.

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

Variable	Units	Value	Source
Value of Travel Time Savings – Automobiles	2020$/hour	$17.80	U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, March 2022.
Value of Travel Time Savings – Trucks	2020$/hour	$32.00	
Vehicle Occupancy – Automobiles	persons/vehicle	1.67	U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, March 2022.
Vehicle Occupancy – Trucks	persons/vehicle	1.00	Assumption

Variable	Units	Value	Source
Peak Period Hours – AM	hours	2	Assumption
Peak Period Hours – PM	hours	2	
Non-Peak Period Hours	hours	14	Assumed that volume is negligible for 6 hours each day (e.g., 12 AM to 6 AM). The remaining 18 hours minus the AM and PM peak period hours is the number of non-peak period hours.
Percent of Daily Travel during Peak Hours	%	32.8%	California DOT, Cal-B/C v8.1 Table: Demand for Travel during Peak Period (2021).
Percent of Daily Travel during Non-Peak Hours	%	67.2%	Assumed that the remaining volume outside the AM and PM peak periods are attributable to the 14 non-peak hours.

Table 8. Vehicle Type Distributions

Variable	Units	I-35 (N)	SH-9W	I-35 (S)	SH-153	Source
Percentage of Automobiles	%	80%	89%	80%	89%	ODOT.
Percentage of Trucks	%	20%	11%	20%	11%	

Benefit Estimates

Table 9 outlines the travel time savings over the project life cycle. At a 7 percent discount rate, these savings are estimated to be $307 million, representing 49 million person-hours saved. 89 percent of these savings are attributable to the reduced delays surrounding the interchanges.

Table 9. Estimated Travel Time Savings (Millions of 2020$)

	Over the Study Period	
	Undiscounted	Discounted
Travel Time Savings from Lane Addition	$97.8	$34.5
Travel Time Savings from Interchange Redesign	$858.7	$273.0
Total Travel Time Savings	**$956.5**	**$307.6**

7.2 Safety

The proposed project will provide safety improvements through avoided accident costs along the 6.9-mile northern segment and the 3.5-mile southern segment of I-35.

7.2.1 Avoided Accident Costs

Methodology

Crash predictions were based on historical accident data and the projected growth rate of AADT. Accident data was broken down in to three severity categories: fatality, injury, and property damage only (PDO), and their projected values were used to represent the No-Build scenario. To estimate the accident rate under the Build scenario, these rates were multiplied by a crash modification factor based on increasing the number of lanes from four to six.

Although avoided accident costs can also be attributed to converting the interchanges, a separate crash modification factor was not applied as the total number of accidents attributable to the interchanges was low and the relevant crash modification factor of 0.858 (CMF ID 10761) was almost identical to the crash modification factor for the lane addition.

Assumptions

The costs and crash rates by accident severity used in the analysis are summarized in Table 10.

Table 10. Assumptions Used in the Estimation of Safety Benefits

Variable	Units	Value	Source
Value of a Statistical Life	2020$/accident	$11,600,000	U.S. DOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, Table A-1, (March 2022)
Cost of Injury	2020$/accident	$210,300	
Cost of PDO	2020$/accident	$4,600	
Crash Modification Factor	factor	0.850	CMF Clearinghouse. CMF ID: 7924; CMF Name: Increase from 4 lanes to 6 lanes.
North Segment			
Accident Distribution – Fatality	%	1.1%	2016 to 2020 accident data from ODOT.
Accident Distribution – Injury	%	27.8%	
Accident Distribution – PDO	%	71.3%	

Variable	Units	Value	Source
Average Number of Accidents per Year	accidents/year	116.4	
South Segment			
Accident Distribution – Fatality	%	0.0%	2016 to 2020 accident data from ODOT.
Accident Distribution – Injury	%	29.8%	
Accident Distribution – PDO	%	70.2%	
Average Number of Accidents per Year	accidents/year	24.8	

Benefit Estimates

Table 11 contains the total accident costs avoided over the lifecycle of the project, split by accident type. The improved safety and reduced accident costs obtained from the project components result in social cost savings of $32. million, discounted at 7 percent. During the 20-year study period, it is estimated that 5 fatality accidents, 153 injury accidents, and 385 PDO accidents will be avoided.

Table 11. Estimated Safety Benefits (Millions of 2020$)

	Over the Study Period	
	Undiscounted	**Discounted**
Avoided Fatality Costs	$55.6	$20.3
Avoided Injury Costs	$32.1	$11.7
Avoided PDO Costs	$1.8	$0.6
Total Safety Benefits	$87.8	$32.0

7.3 Environmental Sustainability

Environmental costs are an increasingly considered important component in the evaluation of transportation projects. The main environmental impact of vehicle use is exhaust emissions, which impose wide-ranging social costs on people, material, and vegetation. The negative effects of pollution depend not only on the quantity of pollution produced, but also the types of pollutants emitted as well as the local environmental conditions into which the pollution is released.

The proposed project is expected to affect emissions in two ways:

1. Through the change in emission rates generated from the changes in speeds; and

2. Through the avoidance of emissions generated from less time spent idling at intersections.

Methodology

The cost of emissions is calculated by multiplying the vehicle miles travelled by the emissions rate, measured in grams per mile, by the cost of emissions, measured in dollars per metric ton. A conversion factor for grams to metric tons is applied.

To calculate the cost of emissions from idling, as discussed in Section 6, the number of hours spent idling are converted to equivalent vehicle miles travelled using a speed of 2.5 mph. This speed is the lowest speed available in the emission factor data. The equivalent vehicle miles travelled are then multiplied by the emission rate and the cost per metric ton.

Assumptions

The list of assumptions used in the estimation of avoided emissions costs are summarized in Table 12.

Table 12. Assumptions Used in the Estimation of Environmental Sustainability Benefits

	Unit	Value	Source
Nitrogen Oxides (NOx)	$/metric ton	Varies by year	US DOT, Benefit-Cost Analysis Guidance for Discretionary Grants Program, March 2022 Revised; Table A-6.
Sulfur Oxides (SOx)	$/metric ton	Varies by year	
Fine Particulate Matter (PM2.5)	$/metric ton	Varies by year	
Carbon Dioxide (CO2)	$/metric ton	Varies by year	
NOx Emission Rate	grams/mile	Varies by year, speed, and vehicle	Estimates from MOVES run based on McClain County, Oklahoma. Speed bins of 2.5 mph were used to represent idling vehicles. Truck data is based on combination short-haul trucks using diesel fuel. Values were gathered for 2020, 2030, 2040, 2050, and interpolation was used to estimate years in-between.
SOx Emission Rate	grams/mile	Varies by year, speed, and vehicle	
PM2.5 Emission Rate	grams/mile	Varies by year, speed, and vehicle	
CO2 Emission Rate	grams/mile	Varies by year, speed, and vehicle	

Benefit Estimates

As a result of changes in speeds and the decreased time spent idling, the project is estimated to decrease greenhouse gas (GHG) emissions by 96,244 metric tons and decrease criteria air contaminant (CAC) emissions by 189 metric tons over the project life cycle.

Table 13 shows the benefits from reduced emissions, which amount to $2.2 million, discounted based on USDOT guidance; about 76% of this amount comes the value of reduced greenhouse gas emissions.

Table 13. Estimated Environmental Sustainability Benefits (Millions of 2020$)

	Over the Study Period	
	Undiscounted	**Discounted**
Avoided Cost of GHG Emissions	$3.1	$1.6
Avoided Cost of CAC Emissions	$2.1	$0.5
Total Environmental Sustainability Benefits	$5.3	$2.2

7.3.2 State of Good Repair

To quantify the benefits associated with maintaining the existing transportation network in a state of good repair, the incremental operations and maintenance (O&M) costs and the residual value of the assets are captured.

Methodology

The O&M cost savings are estimated based on the difference in costs between the No-Build and Build cases. The Build estimates are subtracted from No Build estimates to determine the incremental O&M costs. Positive values indicate operations and maintenance cost savings, a net benefit, while negative values indicate increased operations and maintenance costs, a net incremental cost of the project. Due to additional bridge rehabilitation and more frequent asphalt resurfacing in the No-Build scenario, there are incremental O&M cost savings despite the increase in lane-miles and annual routine maintenance costs.

The residual value is based on straight-line depreciation of the construction costs using a useful life of 50 years plus the total right of way costs.

Assumptions

The table list the specific assumptions for this benefit.

Table 14. Assumptions Used in the Estimation of State of Good Repair Benefits

Variable	Units	Value	Source/Comment
Annual Routine Maintenance, No-Build	2022$	$385,000	
Annual Routine Maintenance, Build	2022$	$410,000	
Pavement Maintenance, No-Build	2022$	$28,500,000	$4,700,000 every 7 years to resurface 28 lane-miles of asphalt; $25,000 every 5 years for center-line striping; $14,000,000 after 20 years to replace 20 lane-miles of concrete.
Pavement Maintenance, Build	2022$	$28,175,000	$7,000,000 every 10 years to resurface 42 lane-miles of asphalt; $125,000 every 5 years for center-line striping; $14,000,000 after 20 years to replace 20 lane-miles of concrete.
Bridge Maintenance, No-Build	2022$	$300,000	Silane treatment for three new bridges.
Bridge Maintenance, Build	2022$	$2,000,000	$1,000,000 for bridge rehabilitation in 2030; $1,000,000 for bridge rehabilitation in 2035.
Useful Life of Project	years	50	Assumption

Table 15. O&M Cost Schedule

Year	No Build			Build		
	Pavement	Bridge	Annual Routine Costs	Pavement	Bridge	Annual Routine Costs
2026			$385,000		$300,000	$410,000
2027	$25,000		$385,000			$410,000
2028	$4,700,000		$385,000			$410,000
2029			$385,000			$410,000
2030		$1,000,000	$385,000	$125,000		$410,000
2031			$385,000			$410,000
2032	$25,000		$385,000			$410,000
2033			$385,000			$410,000

Year	No Build			Build		
	Pavement	Bridge	Annual Routine Costs	Pavement	Bridge	Annual Routine Costs
2034			$385,000			$410,000
2035	$4,700,000	$1,000,000	$385,000	$7,125,000		$410,000
2036			$385,000			$410,000
2037	$25,000		$385,000			$410,000
2038			$385,000			$410,000
2039			$385,000			$410,000
2040			$385,000	$125,000		$410,000
2041			$385,000			$410,000
2042	$18,725,000		$385,000	$14,000,000		$410,000
2043			$385,000			$410,000
2044			$385,000			$410,000
2045			$385,000	$7,125,000		$410,000
Total	**$28,200,000**	**$2,000,000**	**$7,700,000**	**$28,500,000**	**$300,000**	**$8,200,000**
Grand Total		**$37,515,000**			**$36,290,000**	

Benefit Estimates

Table 16 displays the state of good repair benefits over the project life cycle. The discounted value of these benefits is $14.7 million. Due to the timing of the O&M costs in the No-Build scenario, the discounted incremental O&M savings are greater than the undiscounted savings.

Table 16. Estimated State of Good Repair Benefits (Millions of 2020$)

	Over the Study Period	
	Undiscounted	Discounted
Incremental O&M Savings	$0.8	$1.9
Residual Value of Assets	$69.9	$12.9
Total State of Good Repair Benefits	$70.7	$14.7

8 Summary of Findings and BCA Outcomes

The table below summarizes the BCA findings. Annual costs and benefits are computed over the lifecycle of the project and discounted at a rate of 7 percent, with the exception of GHG emissions which are discounted at a rate of 3 percent.

With the 7 percent discount rate, over the 20-year study period the $100.3 million investment would result in $357.1 million in total benefits, net present value of $256.8 million, benefit-cost ratio of 3.6 and an internal rate of return of 21.2 percent.

Table 17. Overall Results of the Benefit-Cost Analysis (Millions of 2020$)

Evaluation Metrics	Undiscounted	Discounted
Total Benefits	$1,121.9	$357.1
Total Costs	$128.4	$100.3
Net Present Value (NPV)	$993.5	$256.8
Benefit-Cost Ratio (BCR)	8.7	3.6
Payback Period (years)	10.3 years	11.7 years
Return on Investment (ROI)	773%	256%
Internal Rate of Return (IRR)	21.2%	

9 BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on a large number of assumptions and long-term projections, both of which are subject to considerable uncertainty. The primary purpose of the sensitivity analysis is to help identify the “critical variables”—the variables and model parameters whose variations have the greatest impact on the BCA outcomes.

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 sensitivity analysis was conducted with respect to changes in the discount rate, the capital costs, the annual growth of AADT, the hours considered in the peak periods, and the estimated delays in 2050. Table 18 provides the percentage changes in project NPV associated with variations in variables or parameters (listed in row), as indicated in the column headers. The NPV is calculated using a 7 percent discount rate and a 3 percent discount rate for carbon dioxide.

The results of the quantitative assessment of sensitivity show that changes to the number of peak period hours has the largest impact of all the sensitivities ions studied. Changing the number of hours during the daily peak periods from four hours (two AM hours and two PM hours) to six hours increases the project NPV by 127%.

Capital costs present another source of uncertainty. However, given the significant benefits estimated in the BCA, even a 15 percent increase in the capital costs only reduces the BCR to 3.1, which is still notably greater than 1. Through varying inputs that impact the major benefit categories such as travel time savings, the sensitivity analysis shows the project is robust and consistently reports a benefit cost ratio greater than 2.

Table 18. Summary of Quantitative Assessment of Sensitivity

Parameters	Change in Parameters	NPV	Change in NPV	BCR
Baseline	**No change**	**$256.8**		**3.6**
Discount Rate	Change discount rates to 3%	$551.5	115%	5.8
Capital Costs	Increase capital costs by 15%	$241.8	-6%	4.2
	Decrease capital costs by 15%	$271.9	6%	3.1
Volume	Increase annual rate of growth by 0.5pp	$300.7	17%	4.0
	Decrease annual rate of growth by 0.5pp	$228.8	-11%	3.3
Number of Peak Hours	Increase total number of peak hours to 6	$581.7	127%	6.8
	Decrease total number of peak hours to 3	$136.6	-47%	2.4
Delays	Increase 2050 delays by 25%	$291.0	13%	3.9
	Decrease 2050 delays by 25%	$218.8	-15%	3.2