Benefit-Cost Analysis Supplementary Documentation

INFRA Grant Program

I-40 Douglas Blvd. Interchange Reconstruction and Related Widening

Oklahoma Department of Transportation

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Benefit-Cost Analysis Supplementary Documentation

1. Executive Summary

The Benefit-Cost Analysis (BCA) conducted for this INFRA grant application compares the societal benefits associated with the proposed investment to the cost 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 BCA is conducted is the I-40 Douglas Boulevard Interchange Reconstruction and Related Widening Project ("the Project") located in southeastern Oklahoma County, Oklahoma. The project encompasses the Interstate segment from the Industrial Avenue Interchange (to the west of Douglas Boulevard Interchange) to I-240.

This segment of I-40 is a critical element of the National Highway System and the National Highway Freight Network designated as a FHWA Alternative Fuels Corridor for CNG and EV. It carries close to 46,000 vehicles daily, including high volumes of commuter and freight traffic.

The Project, including bridges and interchanges within its extents, was built in the 1960s. It is now well beyond its design life and inadequate for the level of traffic it carries. Congestion and delay are a problem today and are projected to worsen over time, in particular given the recent opening of the Kickapoo Turnpike connecting I-40 to I-44 to the east of the Project area. The engineering analysis shows that under normal peak hour traffic, the I-40 corridor has segments that operate at Level of Service ("LOS") grade E with others at LOS D. Without improvement, conditions will deteriorate to LOS F.

Inadequate capacity and design also contribute to safety issues. Collision rates within the Project area are nearly twice the state average for a similar Interstate facility averaging more than 120 collisions annually. Over the years of 2009-2018, there were 8 fatal accidents and 48 accidents with serious injuries in the Project area. The Douglas Boulevard Interchange features an outdated cloverleaf design and poses safety issues with six weaving segments and deficient merge distances provided at entrance ramps. The bridge structures within the Project limits are also approaching structural deficiency, are too narrow, or are too low to allow for safe passage of trucks on the roadway beneath.

The Project addresses the various concerns with the following specific improvements:

- Widen 6.3 miles of I-40 from four lanes to six lanes between Industrial Boulevard and the I-240 interchange;
- Reconstruct Douglas Boulevard Interchange using a single point urban interchange (SPUI) design that maintains a similar footprint as the current cloverleaf, but with enhanced functionality and improved safety;
- Add sidewalks on both sides of Douglas Boulevard across I-40, providing enhanced connectivity for non-vehicular modes;

- Raise the existing bridge at Westminster Road and lower the I-40 mainline under Post Road to correct the substandard vertical clearances at these two locations;
- Reconstruct the I-40 bridges over Anderson Road to accommodate the widened interstate and to increase vertical clearance;
- Add acceleration and deceleration lanes in the vicinity of Anderson Road Interchange; and
- Widen the bridges on mainline I-40 over the westbound I-240 ramps at the I-40/I-240 Interchange to accommodate six through-lanes.

In summary, the Project modernizes this segment of I-40, correcting substandard geometry, and utilizes an innovative urban interchange design at Douglas Boulevard.

The table below provides a summary of infrastructure improvements and associated benefits.

Table ES- 1. Summary of Project Infrastructure Improvements and Associated Quantified Benefits

Current Status or Baseline & Problems to be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Population Affected by Impacts	Economic Benefit/Impact	Summary of Results
The stretch of I-40 from Industrial through Douglas Interchange to I-240 is now well beyond its design life and inadequate for the level of traffic it carries. During peak hours, multiple segments operate at LOS E. Conditions are forecasted to deteriorate to LOS F without improvements. Inadequate capacity and design also contribute to safety issues and a high accident rate. The Douglas Boulevard Interchange in particular is an outdated and dangerous design for the level of traffic it carries. The bridge structures within the Project area are approaching structural deficiency, are too narrow, or too low to allow for safe passage of trucks on the roadway beneath.	The Project addresses the various concerns with improvements that include mainline widening from 4 to 6 lanes, reconstruction of the Douglas Boulevard Interchange, correction, or reconstruction of substandard bridges, and addition of acceleration lanes at the Anderson Road Interchange.	Safety: reduction in number of crashes due to road widening and interchange improvements	Auto Users, Truck Operators	Reductions in fatalities, injuries, and property damage, reduction in accident costs on highway segment.	$59.0 million in accident cost savings.
		Agency cost savings due to infrastructure renewal	Agency operating I-40; Oklahoma residents	Reduction in maintenance, rehabilitation and repair costs of road and bridges due to inadequate design.	$12.2 million in maintenance cost savings.
		Congestion reduction – reduction in travel times	Auto Users, Truck Operators	Travel time savings due to additional capacity with road widening on I-40 mainline and interchange improvements	$29.0 million in travel time savings on I-40 mainline $15.5 million in travel time savings due to interchange improvements
		Emission Impacts	Auto Users, Truck Operators	Increased speed impact on emissions in the Build case	-$0.06 million in emission cost impact
		State of good repair	Agency operating I-40; Oklahoma residents	Residual value of investment	$12.2 million in residual value

Note: All monetary values in the table above are in millions of 2019 dollars discounted using a real discount rate of 7 percent. Benefits calculated over 20 years 2026-2045.

The period of analysis used in the estimation of benefits and costs spans from 2019 to 2045, which include 3 years of construction and 20 years of operations. Future project construction and development costs are estimated at $108.7 million in 2020 dollars. In addition, funds previously spent on engineering, design, environmental assessment, utilities and right of way amount to $5.4 million for a total construction and development cost of $114.2 million. For the purpose of this BCA, all costs were de-escalated or inflated to 2019 dollars. The adjusted costs amount to $112.3 million in 2019 undiscounted dollars and $78.3 million discounted at 7 percent. Over the analysis period, the project will require major maintenance/resurfacing expenditures estimated at $6.5 million in 2020 dollars, $6.4 million in 2019 dollars undiscounted, or $1.5 million in discounted at 7 percent.

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 outlined in this document, the project is expected to generate $127.9 million in discounted benefits and $78.3 million in discounted capital costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value of $49.6 million and a Benefit/Cost Ratio of 1.61 as shown in Table ES- 2.

Table ES- 2: Summary of BCA Outcomes, in Millions of Dollars of 2019*

Project Evaluation Metric	Undiscounted	Present Value at 7% Discount Rate	Present Value at 3% Discount Rate
Total Benefits	$414.1	$127.9	$242.3
Total O&M Costs	$6.4	$1.5	$3.3
Total Construction Costs	$112.3	$78.3	$95.8
Net Present Value	$301.8	$49.6	$146.4
Benefit / Cost Ratio	3.63	1.61	2.49
Internal Rate of Return (%)	12.5%		

**Unless indicated otherwise*

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

State of Good Repair

- The project will bring major renewal to aging Infrastructure, upgrading it to modern designs and capacity requirements.

Improvements in System Reliability

- Improvements in road capacity and reduction in traffic congestion typically improve the reliability of travel times. Reliability will also improve as a result of reduction in the number of accidents and corresponding delays when lanes are blocked with disabled vehicles or during times of routine maintenance. Currently, accident-related delays occur approximately once every three weeks, causing hours of delay per occurrence.
- System reliability improvements will benefit both automobiles as well as trucks improving the transportation schedules and thus the efficiency of goods movement and operational efficiency of shippers and receivers of freight.

2. Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the I-40 Douglas Boulevard Interchange Reconstruction and Related Widening Project (the Project) in Oklahoma County, Oklahoma.

The remainder of this document is organized as follows:

- Section 3, Methodological Framework, introduces the conceptual framework used in the BCA.
- Section 4, Project Overview, provides an overview of the project, including a brief description of existing conditions and the proposed alternative; a summary of cost estimates and schedule; and a description of the types of effects that the project is expected to generate.
- Section 5, General Assumptions, discusses the general assumptions used in the estimation of project costs and benefits.
- Section 6, Demand Projections, shows the estimates of travel demand and traffic growth.
- Section 7, Benefits Measurement, Data and Assumptions, presents specific data elements and assumptions pertaining to the long-term outcomes, along with associated benefit estimates.
- Section 8, Summary of Findings and BCA Outcomes, introduces estimates of the Project's Net Present Value (NPV), its Benefit/Cost Ratio (BCR) and other project evaluation metrics
- Section 9, BCA Sensitivity Analysis, provides the results of the sensitivity analysis.

Additional data tables are provided within the BCA model including annual estimates of benefits and costs to assist the U.S. Department of Transportation (USDOT) in its review of the application.[1]

3. 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.[2]

[1] While the models and software themselves do not accompany this appendix, they are provided separately as part of the application submission.
[2] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 2021.

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.[3]

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 the FY2021 INFRA NOFO, Section D.2.b.vii;
- 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); and
- Conducting a sensitivity analysis to assess the impacts of changes in key input assumptions.

4. Project Overview

4.1 Project Description, Current Conditions and Challenges

The I-40 Douglas Boulevard Interchange Reconstruction and Related Widening Project ("the Project") is located in southeastern Oklahoma County, Oklahoma. It encompasses the Interstate segment from the Industrial Avenue Interchange (to the west of the Douglas Boulevard Interchange) to I-240, covering a distance of about 6.3 miles.

This segment of I-40 is a critical element of the National Highway System and the National Highway Freight Network designated as an FHWA Alternative Fuels Corridor for CNG and EV. It carries close to 46,000 vehicles daily, including high volumes of commuter traffic. The Industrial Avenue and Douglas Avenue interchanges on the west edge of the Project provide access to Tinker Air Force Base ("Tinker"), the largest single-site employer in the state of Oklahoma with 26,000 employees and an anchor for a number of aircraft related businesses in the area. Tinker provides maintenance and repair for military aircraft, serving 92 US Air Force bases and 46 foreign nations. While many aircraft are flown into Tinker for maintenance, the base ships and receives the bulk of its goods and supplies via truck. In fact, I-40 has one of the highest interstate truck volumes in Oklahoma, almost 8,000 each day. This includes over 6,900 per day through the Project segment.

The I-40 segment in the Project area, including the interchanges, was built in the 1960s. It is well beyond its design life and inadequate for the level of traffic it now carries. Congestion and delay are a problem today, and are projected to worsen with traffic expected to grow by 1.3% annually through 2045 due to increasing development in eastern Oklahoma County and throughout the

[3] Ibid.

region. In addition to this annual growth, the Kickapoo Turnpike project connecting I-40 to I-44 to the east of the Project area opened in January 2021, and is expected to add over 2,000 vehicles per day to this segment of I-40 in the short-term and 3,400 vehicles by 2045.

The engineering analysis shows that under normal peak hour traffic, the I-40 corridor has segments that operate at Level of Service ("LOS") E (i.e., speeds below posted speed limit as the roadway approaches capacity). Without improvement, LOS F conditions (i.e., traffic flow is irregular and speeds vary substantially because of congestion) will result along the corridor with significant volume constraints at either end of the Project corridor.

Inadequate capacity and design also contribute to safety issues. In particular, the Douglas Boulevard Interchange is an outdated cloverleaf design that features tight weave movements (350-500' distance) on Douglas and on the I-40 collector-distributor (C-D), yield conditions at the outer ramp merge points with the I-40 C-D, limited weaving distance from the existing Industrial Boulevard west side ramps (600'), and less than 100' or merge/diverge distance at the east side ramps. Acceleration and deceleration lane lengths at the Industrial Avenue (west side) and Anderson Road Interchanges are inadequate, making it difficult for traffic to safely enter and exit I-40. In fact, collision rates within the Project area are nearly twice the state average for a similar Interstate facility averaging more than 120 collisions annually. Over the years of 2009-2018, there were 8 fatalities and 48 serious injuries in the Project area. The interchange areas at Douglas and Anderson have an average of more than 70 collisions per year. This is in part due to inadequate acceleration and deceleration lane lengths, tight ramp curves, short weaves, and the need for merge lanes at Douglas Boulevard. In addition, there is congestion throughout the Project caused by inadequate capacity. Accidents also contribute to "non-recurring" congestion as lanes may be temporarily blocked by involved vehicles, or closed to investigate an accident.

The bridge structures on the Project are approaching structural deficiency and are too narrow. At the same time, bridge structures over the Project have only minimal clearance for semi-trucks to pass safely underneath without causing damage to the structures. For example, the bridges over Anderson Road require repairs approximately every five years due to damage from trucks with tall loads hitting the bridge as they pass underneath.

The Project addresses these concerns with the following specific improvements:

- Widen 6.3 miles of I-40 from four lanes to six lanes between Industrial Boulevard and the I-240 interchange. The existing pavement will be replaced with new asphalt, and inside shoulders will be widened to 10-feet per current standards. Median barrier will be used to separate the east and westbound lanes.
- Reconstruct Douglas Boulevard Interchange using a single point urban interchange (SPUI) design that maintains a similar footprint, but with enhanced functionality, improved safety, and pedestrian connectivity. This includes removal of the existing out-of-service bridge at Engle Road, and removal of the east side ramps and associated short distance weaves at Industrial Blvd.
- Adds 6-foot separated sidewalks on both sides of Douglas Boulevard over I-40.

- Raises the existing bridge at Westminster Road approximately one foot to correct the substandard vertical clearance. This innovate technique will allow for widening of I-40 under the existing bridge.
- Lowers the profile of I-40 under Post Road to achieve sufficient vertical clearance.
- Reconstructs the I-40 bridges over Anderson Road with a single 117-foot-wide prestressed concrete beam bridge to accommodate the widened interstate and to increase vertical clearance.
- Adds acceleration and deceleration lanes in the vicinity of Anderson Road Interchange.
- Widens the bridges on mainline I-40 over the westbound I-240 ramps at the I-40/I-240 Interchange with a single 117-foot-wide prestressed concrete beam bridge to accommodate six through-lanes on I-40.

In summary, the Project modernizes this segment of I-40, correcting substandard geometry and utilizing an innovative urban interchange design at Douglas Boulevard.

4.2 Base Case and Alternative

The Base Case for the I-40 Douglas Boulevard Interchange Reconstruction and Related Widening Project 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 deficiencies. Current challenges will continue, including:

- Travel delays to commuter, business, and truck traffic due to recurring and non-recurring congestion;
- High accident rates, including fatalities and serious injuries; and
- Structural bridge deficiencies with high maintenance costs.

The Alternative Case is defined as the Build scenario that includes all project components outlined above.

4.3 Types of Impacts

The proposed project is expected to have the following impacts:

- Reduction in the number of accidents and corresponding social accident costs and travel delay costs;
- Reduction in travel times for automobiles and trucks;
- Improvement in travel time reliability for automobile and trucks;
- Environmental impacts due to changes in average speeds on the facility, and;
- Improvement in state of good repair with reduction in highway maintenance and repair costs.

4.4 Project Cost and Schedule[4]

Total project capital construction costs are estimated at $108.7 million in 2020 dollars. In addition, $5.4 million were spent over the years 2015 to 2021 in relation to this project on preliminary engineering, design, environmental assessment, utilities and right of way purchase for a total project cost of $114.2 million. For the purpose of this BCA, all costs were adjusted to 2019 dollars using a Gross Domestic Product (GDP) deflator and inflation factors.[5] The adjusted project development and construction cost amounts then to $112.3 million in 2019 undiscounted dollars and $78.3 million discounted at 7 percent.

The project will require periodic maintenance and major maintenance/resurfacing work. The requirements are estimated at $1.0 million in 2026 and $5.5 million in 2045 (in 2020 dollars). After adjusting to 2019 dollars, total operations and maintenance costs (O&M) are estimated at $6.4 million in constant dollars and $1.5 million discounted at 7 percent.

All of above Project costs are summarized in the table below.

Table 1. Summary of Costs, Millions of 2019 Dollars

	Over the Project Lifecycle		
	In Constant Dollars	**Discounted at 7 Percent**	**Discounted at 3 Percent**
Construction & Development Costs	$112.3	$78.3	$95.8
Operations and Maintenance	$6.4	$1.5	$3.3
Total	**$118.7**	**$79.8**	**$99.1**

Project construction is anticipated to start in May of 2023 and to be completed by the end of 2025. For the purposes of this BCA, 2026 is assumed as the first year of full operations. It is noted, however, that capital construction costs are anticipated to be distributed over the years 2023 to 2026 with the last payment instalment taking place in December 2026.

4.5 Alignment with Project Requirements

The main benefit categories associated with the project are mapped into the project requirements for large projects specified in Section D.2.b.vii in the Notice of Funding Opportunity (NOFO) as shown in the table below. These requirements link to the infrastructure goals listed under 23 U.S.C. 150 and are also aligned with the key program objectives of supporting economic vitality as discussed in the NOFO.

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[4] Unless stated otherwise, all cost estimates in this section are in millions of dollars of 2019, discounted to 2019 using a 7 percent real discount rate.

[5] The adjustment of construction costs amounted to dividing 2020 costs by the deflator index of 1.03952 based on the GDP deflators for the years 2019 - 2020 (Office of Management and Budget of the White House, Table 10.1, https://www.whitehouse.gov/omb/historical-tables/). Previously spent funds in years 2016 to 2018 were inflated to 2019 using inflation factors recommended by US DOT (US DOT Benefit-Cost Analysis for Discretionary Grant Programs, February 2021, Table A-7).

Table 2. Benefit Categories and Expected Alignment with Project Requirements

Project Requirements	Benefit or Impact Categories	Description	Monetized	Qualitative
Safety	Reduction in number of traffic crashes, fatalities and injuries	Reduction in property losses, injuries, and deaths due to improved interchange design, acceleration and deceleration lanes, additional travel lanes.	Yes	
Infrastructure Condition	Agency costs savings – Reduction in highway maintenance costs	Reduction in the costs of maintenance and repair of road and bridges due to inadequate design and clearance issues for trucks using the Interstate.	Yes	
	State of good repair	Renewal of infrastructure assets with outdated design that is also beyond its design life.	Yes (residual value)	Yes
Congestion reduction	Reduction in travel times on facility	Travel time savings for roadway users due to additional capacity with road widening and interchange improvements.	Yes	
System reliability	More reliable/consistent travel times	Reduction in congestion also typically improves the reliability of travel times. Reliability will also improve as a result of reduction in the number of accidents and corresponding non-recurrent delays.		Yes
Freight movements and economic vitality	Travel time savings	Travel time savings for truck operators due to additional capacity with road widening. (Also captured under congestion reduction).	Yes	
	More reliable/consistent travel times	Improvement in reliability of travel times (Also captured under system reliability)		Yes
Environmental Emissions Impacts	Increase emissions	The project will result in a small increase in emissions due to improvement in average speeds	Yes	

5. General Assumptions

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

The monetized benefits and costs are estimated in 2019 dollars with future dollars discounted in compliance with INFRA requirements using a 7 percent real rate. A 3 percent discount rate is used for sensitivity analysis.

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

- Input prices are expressed in 2019 dollars;
- The period of analysis begins in 2019 and ends in 2045. It includes project development activities, 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;
- Opening year demand and benefits are inputs to the BCA and assumed to be fully realized after construction is finished and project starts operations in 2026 (no ramp-up); and
- Unless specified otherwise, the results shown in this document correspond to the effects of the full Build alternative as described in Section 4.1.

6. Demand Projections

The traffic forecast is a critical component of the benefit-cost analysis as many benefits are driven by vehicle miles of travel within the Project area.

The traffic data used in this BCA comes from an I-40 East Corridor traffic study conducted in 2018 for ODOT[6] and an interstate Access Justification Report (AJR) completed by ODOT in 2020.[7] The current volumes were validated with ODOT's 2019 Traffic Monitoring System. Both studies had a robust count collection plan for short term hourly counts and turning movements within their study area. These 24-hour counts were converted to AADT counts using seasonal and axle adjustment factors derived from ODOT's statewide automatic vehicle classifiers. These counts included the traffic anticipated from the Kickapoo Turnpike.

The daily estimates were broken down into three segments: (1) Industrial Avenue to Douglas Interchange; (2) Douglas Interchange to Anderson Interchange, and (3) Anderson Interchange to I-40, for the years 2017 and 2045, and direction of travel, eastbound (EB) and westbound (WB), as shown in Table 3 Hourly Traffic Volumes in Project Area, by Segment and Direction of Travel, 2017 and 2045. The table shows that the volume of traffic (eastbound and westbound combined) varies by segment. In 2017, the volume of traffic was estimated at 38,380 vehicles per day for the segment Anderson Interchange to I-240, and 55,595 vehicles per day for the segment Industrial to Douglas. The segment between Douglas Interchange and Anderson Interchange carries an average of 45,960 vehicles each day. By 2045, traffic volume is forecasted to increase to 55,880, 84,580, and 66,640 on the respective segments.

The implied rate of growth in traffic is used to interpolate volumes for years in-between 2017 and 2045. The same traffic volume is assumed under Build and No-Build conditions.[8]

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[6] Garver, *EC-1457A-I-40 Corridor, Oklahoma County, Oklahoma. Preliminary Traffic Study,* Prepared for Oklahoma Department of Transportation, March 2018.

[7] Oklahoma Department of Transportation, Access Justification Report, I-40 and Douglas Boulevard Interchange, Oklahoma County, Oklahoma, J/P 28992(04), May 2020.

[8] On the segment Industrial to Douglas, the Build volumes are lower than under No Build by about 5% due to closure of the west side Industrial ramps. These lower Build vehicle volumes are used in the BCA for calculation of mainline travel time savings.

Table 3. Hourly Traffic Volumes in Project Area, by Segment and Direction of Travel, 2017 and 2045

TIME	Industrial to Douglas (Build)				Douglas to Anderson				Anderson to I-240			
	2017		2045		2017		2045		2017		2045	
	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB
00:00	435	540	661	801	357	442	514	630	298	370	431	529
01:00	234	303	356	450	192	248	277	354	160	208	232	297
02:00	96	50	146	74	79	41	113	58	66	34	95	49
03:00	90	74	136	110	74	61	106	86	61	51	89	73
04:00	91	148	139	220	75	121	108	173	62	102	90	145
05:00	131	441	199	656	107	361	155	515	90	303	130	433
06:00	642	1,351	976	2,007	526	1,105	759	1,578	439	928	636	1,325
07:00	1,237	2,682	1,880	3,983	1,014	2,194	1,462	3,132	847	1,841	1,225	2,630
08:00	1,660	3,295	2,730	5,095	1,095	3,110	1,730	4,575	1,015	2,470	1,615	3,675
09:00	1,076	1,734	1,635	2,574	882	1,418	1,271	2,024	736	1,190	1,065	1,699
10:00	1,016	1,328	1,545	1,973	833	1,087	1,201	1,551	696	912	1,006	1,302
11:00	1,051	1,423	1,598	2,113	862	1,164	1,243	1,661	720	976	1,041	1,395
12:00	1,263	1,567	1,919	2,326	1,035	1,282	1,493	1,829	864	1,075	1,250	1,536
13:00	1,343	1,230	2,042	1,827	1,101	1,006	1,588	1,436	919	844	1,330	1,206
14:00	1,480	1,257	2,250	1,867	1,213	1,028	1,750	1,468	1,013	863	1,466	1,232
15:00	2,096	1,755	3,187	2,606	1,718	1,436	2,478	2,049	1,435	1,205	2,076	1,721
16:00	3,380	1,815	5,280	3,195	3,400	1,140	4,935	2,010	2,740	1,005	3,995	1,820
17:00	2,960	2,011	4,500	2,986	2,427	1,645	3,499	2,348	2,026	1,380	2,932	1,971
18:00	2,501	1,587	3,802	2,356	2,050	1,298	2,956	1,853	1,712	1,089	2,477	1,556
19:00	1,479	1,143	2,248	1,697	1,212	935	1,748	1,334	1,012	784	1,464	1,120
20:00	1,136	789	1,728	1,171	932	645	1,343	921	778	541	1,125	773
21:00	951	657	1,445	975	779	537	1,124	767	651	451	942	644
22:00	704	409	1,071	608	577	335	833	478	482	281	697	401
23:00	537	417	816	620	440	341	635	487	368	286	532	409
Total	**27,590**	**28,005**	**42,290**	**42,290**	**22,980**	**22,980**	**33,320**	**33,320**	**19,190**	**19,190**	**27,940**	**27,940**

Source: ODOT I-40 Corridor Traffic Study, 2018 and ODOT Access Justification Report, 2020.

Table 3 (continued)

TIME	West of Industrial				Industrial to Douglas (No Build)			
	2017		2045		2017		2045	
	EB	WB	EB	WB	EB	WB	EB	WB
00:00	478	579	702	850	456	560	684	832
01:00	257	325	378	477	246	314	369	467
02:00	105	53	155	78	101	52	151	77
03:00	99	79	145	117	94	77	141	114
04:00	100	159	147	233	96	154	144	228
05:00	144	474	211	696	137	458	206	680
06:00	705	1,451	1,035	2,129	673	1,402	1,010	2,083
07:00	1,359	2,880	1,995	4,227	1,297	2,783	1,945	4,135
08:00	2,325	3,595	3,485	5,433	1,735	3,610	2,815	5,420
09:00	1,182	1,861	1,734	2,732	1,128	1,799	1,692	2,672
10:00	1,117	1,426	1,639	2,093	1,066	1,378	1,598	2,048
11:00	1,155	1,527	1,695	2,242	1,102	1,476	1,653	2,193
12:00	1,388	1,682	2,036	2,469	1,324	1,625	1,986	2,415
13:00	1,476	1,321	2,166	1,939	1,409	1,276	2,113	1,896
14:00	1,627	1,350	2,387	1,981	1,552	1,304	2,328	1,938
15:00	2,304	1,884	3,381	2,766	2,199	1,821	3,297	2,705
16:00	3,760	2,480	5,580	3,918	3,870	1,890	5,705	3,280
17:00	3,253	2,159	4,774	3,169	3,105	2,086	4,657	3,099
18:00	2,748	1,704	4,033	2,501	2,623	1,646	3,934	2,446
19:00	1,625	1,227	2,385	1,801	1,551	1,186	2,326	1,761
20:00	1,249	847	1,833	1,243	1,192	818	1,787	1,216
21:00	1,045	705	1,533	1,035	997	681	1,496	1,012
22:00	774	439	1,136	645	739	425	1,108	631
23:00	590	448	866	657	563	433	845	643
Total	**30,865**	**30,655**	**45,430**	**45,430**	**29,255**	**29,255**	**43,990**	**43,990**

Source: ODOT I-40 Corridor Traffic Study, 2018 and ODOT Access Justification Report, 2020

7. Benefits Measurement, Data and Assumptions

This section describes the measurement approach used for each quantifiable benefit or impact category identified in Table 2 and provides an overview of the associated methodology, assumptions, and estimates.

7.1 Safety Benefits Impacts

Safety benefits include reduction in expected number of accidents due to improvements in interchange design and I-40 mainline capacity. These benefits are estimated based on a historical accident profile, assuming the same profile (accident rates) for future years under No Build and using a Crash Modification Factor (CMF) methodology for the Build scenario.

Historical accident statistics in the Project area were provided by ODOT's Collision Analysis and Safety Branch. This data was divided into three sub-areas corresponding to major categories of Project improvements with likely impacts on safety: (1) I-40 mainline, (2) Douglas Interchange, and (3) Anderson Interchange. This data is shown in Table 4. The data shows that over the 10-year period between 2009 and 2018 there were 1,231 accidents in the Project area which resulted in 8 fatalities, 48 serious injuries, and several less serious injuries and property damage. As outlined in Section 4.1, there are several factors contributing to this high number of accidents, including inadequate capacity, outdated interchange design, and acceleration/deceleration lanes that are too short.

It is assumed that in future years under No Build, the number of accidents will grow at the same rate as the overall traffic reflecting the same accident rates in the same driving conditions. For the purpose of this BCA, the data in Table 4 was used to calculate the average annual number of accidents. The initial annual number of accidents was then modeled to increase annually by the rate of traffic growth to derive the expected number of accidents each year under No Build.

Table 4: Number of Accidents in Project Area, 2009-2018, by Severity and I-40 Sub-Area

Accident Severity	I-40 Mainline	Douglas Boulevard Interchange	Anderson Interchange	Total
Property Damage Only	368	338	168	874
Potential Injury	72	79	32	183
Non-incapacitating Injury	42	48	28	118
Serious Injury	27	8	13	48
Fatal	5	1	2	8
Grand Total	**514**	**474**	**243**	**1,231**

Source: ODOT, Collision Analysis & Safety, Traffic Engineering

The Project will improve safety along mainlines and on interchanges by adding additional lanes and redesigning the interchanges as discussed in Section 4.1. To forecast the reduction in accidents due to these improvements, the Crash Modification Factors (CMF) Clearinghouse database was searched to identify similar improvements and the corresponding CMFs. Many such CMFs were identified in the search. CMFs selected for this BCA are presented in the table below. The Build annual number of accidents for each sub-area of I-40 is then forecasted as the number of accidents under No Build multiplied by the CMF factor for that sub-area.[9]

Table 5: Crash Modification Factors (CMFs) Used in the Analysis

CMF ID#	Value	Applied to	Description of Improvement
8336	0.74	Mainlines	Adding additional 12-foot lane. Affects all accidents
474	0.89	Anderson Interchange	Extend acceleration lane by approximately 98 feet. Affects all accidents
475	0.93	Anderson Interchange	Extend deceleration lane by approximately 98 feet. Affects all accidents
478	0.55	Douglas Interchange	Provide a straight ramp instead of a cloverleaf ramp. Affects all accidents.

Source: Crash Modification factors Clearinghouse database, http://www.cmfclearinghouse.org/ .

Safety benefits impacts were then estimated based on the number of accidents, by type, expected under No-Build versus the Build scenario and monetized using the social values of accident costs by type recommended by USDOT. The assumptions used in the estimation of safety benefits are summarized in the table below.

Table 6. Assumptions Used in the Estimation of Safety Benefits

Variable Name	Unit	Value	Source
Fatality	$/Victim	$10,900,000	US DOT BCA Guidance for Discretionary Grant Programs, February 2021; Table A-1.
Serious Injury (MAIS 3)	$/Victim	$1,144,500	US DOT BCA Guidance for Discretionary Grant Programs, February 2021; Table A-1.
Non-Incapacitating Injury (MAIS 2)	$/Victim	$512,300	US DOT BCA Guidance for Discretionary Grant Programs, February 2021; Table A-1.
Possible Injury (MAIS 1)	$/Victim	$32,700	US DOT BCA Guidance for Discretionary Grant Programs, February 2021; Table A-1.
No Injury/ PDO	$/Vehicle	$4,500	US DOT BCA Guidance for Discretionary Grant Programs, February 2021; Table A-1.
Number of fatalities per fatal crash	Number per Crash	1.00	Calculated from crash statistics 2009 to 2018.
Number of injured per injury crash – Serious Injuries	Number per Crash	1.61	Calculated from crash statistics 2009 to 2018.
Number of injured per injury crash – Non-incapacitating injuries	Number per Crash	1.15	Calculated from crash statistics 2009 to 2018.
Number of injured per injury crash – Possible injuries	Number per Crash	1.15	Assumed the same as for non-incapacitating injuries.

[9] A crash analysis performed for the AJR report referenced in Section 6 used the Interactive Highway Safety Design Model (IHSDM) and produced similar overall crash reductions of 25%.The IHSDM analysis used earlier base years and did not include ramp improvements at Anderson but overall sit upports the CMF assumptions used in this BCA.

Variable Name	Unit	Value	Source
Damaged vehicles per PDO crash	Number per Crash	2.03	California Department of Transportation, TASAS Unit, 2010 to 2013 suburban average.

7.2 Agency Cost Savings

As discussed in Section 4.1, the Project structures are now well beyond their design life span. Without replacement or reconstruction, they will require extensive maintenance and repairs to ensure that they are in a condition suitable for operations. Under Build, these expenditures will not be required, and thus will become a saving to ODOT. (Note that operations and maintenance costs of the Project under Build are captured separately under project O&M costs). The estimated maintenance schedule and amounts of expenditures for the No Build scenario are shown below in Table 7. The table shows that the Project is expected to save about $32 million (in undiscounted 2020 dollars) over the Project life.

Table 7: Maintenance Expenditures under No Build (2020 Dollars)

Year	Maintenance & Rehabilitation Costs for I-40	Bridge Rehabilitation Costs	Bridge Damage Repair Costs	Total
2026	$5,500,000	$2,000,000	$100,000	$7,600,000
2030	$5,500,000	$1,000,000	$100,000	$6,600,000
2035	$5,500,000	$1,000,000	$100,000	$6,600,000
2040	$5,500,000		$100,000	$5,600,000
2045	$5,500,000		$100,000	$5,600,000
Total	**$27,500,000**	**$4,000,000**	**$500,000**	**$32,000,000**

Source: ODOT Division 4

7.3 Congestion Reduction

As discussed in Section 4.1, the Project will implement a range of improvements intended to increase capacity and modernize the design to current standards. Additional lanes on the mainline are expected to increase average speeds during peak periods when congestion is most severe and travel times increase. Interchange improvements are expected to reduce delays for vehicles moving through the ramps (getting on or off the mainline). Estimation of these two categories of travel time savings are addressed below.

<u>Increase in Average Speeds on I-40 Mainline</u>

Average speeds and average travel times on the mainline were calculated using Highway Capacity Manual methodology (HCS 7). The network was analyzed in Highway Capacity Software (HCS) for 2017 and 2045, each of these years for No Build and Build scenarios, and separately for each direction of travel (eastbound and westbound), AM Peak and PM Peak. The results are shown in the table below. The estimated speeds were used to calculate travel times under Build and No Build (peak period) for 2017 and 2045 and interpolated for the years between. For the purpose of the calculations, AM Peak was assumed for the hours 7 to 9 AM, and PM Peak was assumed for the hours 4 to 7 PM.

Table 8: Average Speeds on I-40 Mainline, by Year, Direction of Travel, and AM/PM Peak, MPH

	2017				2045			
	Eastbound		Westbound		Eastbound		Westbound	
	AM	PM	AM	PM	AM	PM	AM	PM
No Build	64.5	64.0	63.9	64.4	64.0	59.6	29.4	62.5
Build	66.8	67.3	69.3	69	66.7	64.5	66.8	68.9

Source: ODOT I-40 Traffic Study, 2018 (updated 2021).

Reduction in Delays on Interchanges

Similarly, the arterial delay savings due to the interchange reconfiguration at Douglas Boulevard and Industrial Boulevard was calculated using SimTraffic simulation software to produce a comparison between the current cloverleaf configuration and proposed SPUI configuration. Simulations were conducted for 2017 and 2045, each of these years for No Build and Build scenarios, and separately for AM Peak and PM Peak. The results in terms of vehicle-hours of delay are shown in the table below. These figures were taken directly into the BCA model and interpolated for the years between.

Table 9: Delays on Ramps, by Year, AM/PM Peak; Daily Vehicle-Hours

	2017		2045	
	AM	PM	AM	PM
No Build	185	298	1,146	2,630
Build	151	169	919	2,513

Source: ODOT I-40 Traffic Study, 2018 (updated 2021).

Valuation of Travel Time Savings

Table 10 shows the parameter values that were used to monetize the estimated vehicle hours of travel time savings when driving on the mainline and going through interchanges.

Table 10. Assumptions Used in the Valuation of Travel Time Savings

Variable Name	Unit	Value	Source
Value of Travel Time Savings			US DOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 2021.
Auto (All Trip Purposes)	$/h, per person	$17.90	Value of travel time for all purposes. I-40 is likely to carry commuters as well as users travelling on business.
Truck Drivers	$/h	$30.80	
Average Vehicle Occupancy – Peak Period	persons/ vehicle	1.48	US DOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 2021.
Truck Share in Total Traffic	%	13.0%	ODOT

7.4 Environmental Emissions Impacts

Average speed affects vehicle tailpipe emissions of common air pollutants and greenhouse gases (GHG). Therefore, the Project is expected to have a small impact on vehicle emissions and related emissions costs due to impacts on average speeds.

Emission costs were calculated based on the speeds in the Build and No-Build cases. Emissions factors from the EPA's Motor Vehicle Emission Simulator (MOVES) for carbon dioxide (CO2), nitrogen oxides (NOX), fine particulate matter (PM2.5), and sulfur oxides (SO2) were applied to the vehicles miles travelled, broken out by automobile and trucks to determine the metric tons of emissions produced in each case. The unit values of each air pollutant and CO2 were then applied based on USDOT guidance. Table 11 shows the assumptions.

Table 11. Assumptions Used in the Estimation of Emission Costs

Year	Unit	NOx	SO2	PM2.5	CO2	Source
2019	$/metric ton	$15,700	$40,400	$729,300	$50	US DOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 2021; Table A-6.
2020		$15,700	$40,400	$729,300	$50	
2021		$15,900	$41,300	$742,300	$52	
2022		$16,100	$42,100	$755,500	$53	
2023		$16,400	$43,000	$769,000	$54	
2024		$16,600	$43,900	$782,700	$55	
2025		$16,800	$44,900	$796,600	$56	
2026		$17,000	$45,500	$807,500	$57	
2027		$17,300	$46,200	$818,600	$58	
2028		$17,500	$46,900	$829,800	$59	
2029		$17,700	$47,600	$841,200	$60	
2030		$18,000	$48,200	$852,700	$61	
2031		$18,000	$48,200	$852,700	$62	
2032		$18,000	$48,200	$852,700	$63	
2033		$18,000	$48,200	$852,700	$64	
2034		$18,000	$48,200	$852,700	$66	
2035		$18,000	$48,200	$852,700	$67	
2036		$18,000	$48,200	$852,700	$68	
2037		$18,000	$48,200	$852,700	$69	
2038		$18,000	$48,200	$852,700	$70	
2039		$18,000	$48,200	$852,700	$71	
2040		$18,000	$48,200	$852,700	$72	
2041		$18,000	$48,200	$852,700	$73	
2042		$18,000	$48,200	$852,700	$75	
2043		$18,000	$48,200	$852,700	$76	
2044		$18,000	$48,200	$852,700	$77	
2045		$18,000	$48,200	$852,700	$78	

7.5 Aggregation of Benefit Estimates

The table below provides the monetary estimates of the quantified and monetized benefits of this Project. Benefits include the residual value of structures at the end of the analysis period which was calculated assuming a design life of 60 years and a straight line depreciation.[10]

The table shows that total Project benefits amount to $127.9 million in 2019 dollars discounted at 7%. Accident cost savings account for the largest share of benefits at $59.0 million (or 46.1 percent of total) followed by travel time savings on the mainline at $29.0 million (22.7 percent of total) and travel time savings on interchanges at $15.5 million (12.1 percent of total). The table also shows that the project results in a small emissions cost which is due to an increase in average speed on the facility under the Build conditions.

Table 12: Summary of Project Benefits; Millions of 2019 Dollars

Benefit Categories	Over Project Lifecycle		
	Undiscounted	Present Value at 7% Discount Rate	Present Value at 3% Discount Rate
Reduction in Accident Costs	$172.2	$59.0	$105.9
Travel Time Savings - Mainline	$93.6	$29.0	$55.1
Travel Time Savings - Interchanges	$45.9	$15.5	$28.1
Emissions Costs	-$0.07	-$0.06	-$0.05
Residual Value	$71.1	$12.2	$33.0
Agency Cost Savings	$31.4	$12.2	$20.3
Total Benefits	**$414.1**	**$127.9**	**$242.3**

8. Summary of Findings and BCA Outcomes

The table below summarizes the BCA findings. Annual costs and benefits are estimated over the lifecycle of the project (years from 2019 to 2045).

Table 13. Overall Results of the Benefit Cost Analysis, Millions of 2019 Dollars*

Project Evaluation Metric	Undiscounted	Present Value at 7% Discount Rate	Present Value at 3% Discount Rate
Total Discounted Benefits	$414.1	$127.9	$242.3
Total O&M Costs	$6.4	$1.5	$3.3
Total Discounted Costs	$112.3	$78.3	$95.8
Net Present Value	$301.8	$49.6	$146.4
Benefit / Cost Ratio	3.63	1.61	2.49
Internal Rate of Return (%)	12.5%		

*Unless indicated otherwise

As stated earlier, construction is expected to be completed by the end 2025. Benefits accrue during the operation of the project (over the years 2026-2045).

[10] The design life of 60 years corresponds to current age of the facility.

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 12.5 percent. With a 7 percent real discount rate, the $78.3 million investment would result in $127.9 million in total benefits, Net Present Value of $49.6 million, and a Benefit/Cost ratio of approximately 1.61.

With a 3 percent real discount rate, the Net Present Value of the project is $146.4 million, with a Benefit/Cost ratio of 2.49.

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 sensitivity analysis was conducted with respect to changes in the capital cost estimate, crash modification factors, and the length of the analysis period. The outcomes of the analysis using a discount rate of 7 percent 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.

The changes in the crash modification factors and capital cost estimate have the greatest impact on net present value. The table demonstrates that this project features strong performance even in situations when key input values change in the direction that reduces net benefits. In all such situations examined, the Benefit-Cost Ratio remains above 1.0. It is also noted that when the analysis period (post-construction) is increased from 20 years to 30 years, the Benefit-Cost ratio increases to 1.82.

Table 14. Quantitative Assessment of Sensitivity, Summary

Parameters	Change in Parameter Value	New NPV	% Change in NPV	New B/C Ratio
Capital Cost	25% Reduction	$69.21	39.4%	2.15
	25% Increase	$30.1	-39.4%	1.29
Crash Modification Factors	CMF reduction on mainline from 0.74 to 0.89	$26.32	-47.0%	1.32
	CMF reduction on Douglas Interchange from 0.55 to 0.66	$11.9	-61.8%	1.11
Length of Analysis Period	Extension from 20 years to 30 years	$67.9	36.8%	1.82