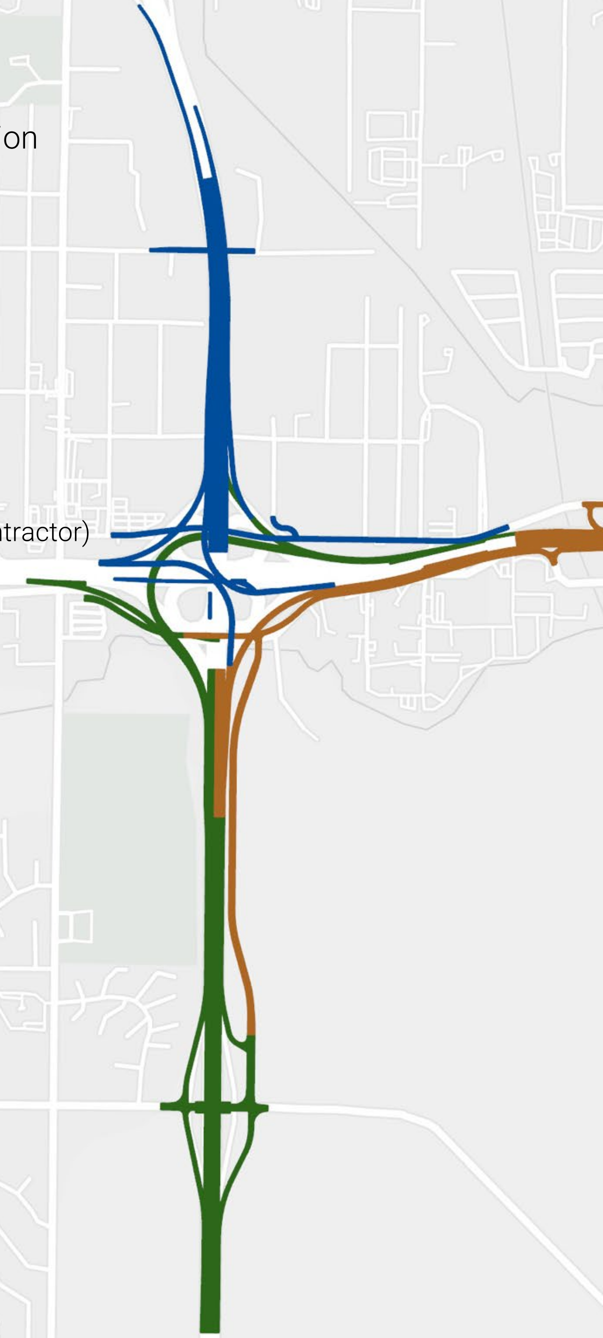
ENHANCING SAFETY AND MOBILITY IN WEST TULSA: I-44 AND US-75 CORRIDOR IMPROVEMENTS

Appendix Report: Project Benefit Cost Analysis

Oklahoma Department of Transportation

MAY 2022



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1. Overview of Approach

A Benefit Cost Analysis (BCA) was conducted for work phases (WP) 2, 3, and 5 of the I-44/US-75 Interchange, a major part of the overall "Enhancing Safety and Mobility in West Tulsa: I-44 and US-75 Corridor Improvements" project (The Project). The BCA follows the most recent 2022 USDOT guidance for BCAs, which provides both methodological guidance and specific values for monetizing various types of benefits, such as hourly values of travel time, and the economic cost of vehicle crashes (including pedestrian-vehicle incidents), and air emissions. All values from that guidance are in 2020 dollars. All monetary values in the BCA, including costs, are expressed in constant 2020 dollars.

The following general parameters and assumptions have been used in conducting the BCA:

- A real discount rate of 7 percent is applied to all costs and benefits except for carbon emissions reductions, which are discounted at 3 percent.
- A project life cycle of 25 years is assumed, which represents a mid-point between a recommended 20-year horizon of analysis for rehab and replace projects, vs. 30 years for new right-of-way and facilities. The I-44 and US-75 Corridor Improvement Project comprises multiple individual elements reflecting a mix of old and rehabbed infrastructure.
- No residual value is assumed at the close of the 25 years of operation.
- Project construction is assumed to begin in 2024 and end in late 2026, with operation commencing in 2027. Some advanced right-of-way acquisition for interchange construction will occur in the years 2021 – 2024.
- All costs and benefits are in 2020 dollars.
- The year 2020 was used as the base year for discounting; that is, 2020 is considered year zero for discounting.

2. Project Costs

Major capital, maintenance, and bridge rehab and repair costs are summarized in Table 1. These exclude routine maintenance for items such as patching, snow or ice clearance, or other non-capital items.

Table 1: Build and No-Build Capital and Major Rehab Cost Summary in Millions of 2020$

	No-build	Build
Total Maintenance	$43.33	$8.59
I-44/US-75 Maintenance & rehab	$20.00	$8.59
Bridge Rehab	$22.83	
Bridge Damage Repair	$0.51	
Capital Costs	n/a	$207.9

Source: Oklahoma DOT design engineers

2.1. Capital Cost

The estimated capital cost of The Project is $207.9 million in 2020 dollars (including contingency), and is broken down as follows:

- WP 2: $75.85 million
- WP 3: $60.80 million
- WP 5: $71.21 million

2.2. Operations and Maintenance Costs

The Project will result in very little difference in lane mileage compared to the No-Build and as such, no incremental difference in routine lane-related maintenance costs has been assumed. However, as seen in the cost summary, there are significant differences in non-routine maintenance, bridge repair, and rehabilitation costs, and bridge damage costs. Under the No-Build, ODOT engineers estimate that $43.33 million has been and will be spent for non-routine roadway and bridge maintenance, compared with $8.6 million for the Build (i.e., with I-44 and US-75 Corridor Improvement Projects). Except for $9.2 million already spent before today for the existing infrastructure, US-75, these represent significant future life cycle cost savings, which are included as cost offsets for BCA purposes. These prior 9.2 million expenditures are excluded from the BCA; however, if included, the benefit cost ratio is still above 1.0 and demonstrates ODOT's commitment to a state of good repair.

3. Project Benefits

3.1. Monetized Benefits included in the BCA

Four primary categories of benefit have been captured by the BCA: reduced motor vehicle crashes, travel delay savings, logistics (freight) cost savings, and emissions cost reductions. As noted above, life cycle and cost savings were moved to the denominator of the benefit cost ratio calculation, following USDOT BCA guidance. Furthermore, economic benefits such as enhanced productivity (over and above those embodied in travel time savings) are not included. However, the overall improvements in regional accessibility may generate additional productivity benefits, such as agglomeration benefits reflecting the improved ability of employers to access specialized labor.

Crash Reductions: Because much of The Project involves reconfiguring the complex network of US-75 and I-44 interchanges and approach lanes and roadways to the interchanges, a significant share of the anticipated benefits will be reduced vehicular collisions and improved pedestrian safety. To estimate these likely impacts, a detailed data list of all collisions that occurred throughout the I-44 and US-75 Corridor Improvement Projects limits between the years 2014 and 2018, by severity, was collected. Levels of severity were measured on a scale of one to five, including fatal crashes, injury crashes of three degrees of severity, and property-damage-only crashes. These levels of severity are assumed to be roughly equivalent to KABCO scale measurements.

The following count of crashes over the five-year period (covering the full calendar years 2014 through 2018) was obtained from ODOT:

- 408 PDO (property damage only)
- 201 Injury Severity 2 (least severe)
- 134 Injury Severity 3
- 25 Injury Severity 4
- 5 Fatal (including 1 pedestrian fatality)

Table 2 summarizes the accident data, VMT data, and calculations leading to estimated accident reductions.

Table 2. Crash rate reduction calculations

Crash Reductions for Work Packages 2, 3, and 5							
Annual Crashes (2014-2018)	Total	Annual Average	Crashes/MVMT				
PDO	408	81.6	1.10				
Injury Severity 2	201	40.2	0.54				
Injury Severity 3	134	26.8	0.36				
Injury Severity 4	25	5.0	0.07				
Fatal	5	1.0	0.01				
VMT	2016 Actual	2040 Projected					
WP2	29,739,324	42,872,225					
WP3	28,454,999	38,123,064					
WP5	15,673,173	21,149,031					
Total	73,867,496	102,144,319					
Assumed Crash Reduction Factor							
45%							
Projected Annual Crashes (No Build)	2016	2025	2030	2035	2040	2045	2050
PDO	81.60	92.15	98.59	105.48	112.85	120.73	129.17
Injury Severity 2	40.20	45.40	48.57	51.96	55.59	59.48	63.63
Injury Severity 3	26.80	30.26	32.38	34.64	37.06	39.65	42.42
Injury Severity 4	5.00	5.65	6.04	6.46	6.91	7.40	7.91
Fatal	1.00	1.13	1.21	1.29	1.38	1.48	1.58
Projected Annual Crash Reduction (Build)	2016	2025	2030	2035	2040	2045	2050
PDO	n/a	41.47	44.36	47.46	50.78	54.33	58.13
Injury Severity 2	n/a	20.43	21.86	23.38	25.02	26.77	28.64
Injury Severity 3	n/a	13.62	14.57	15.59	16.68	17.84	19.09
Injury Severity 4	n/a	2.54	2.72	2.91	3.11	3.33	3.56
Fatal	n/a	0.51	0.54	0.58	0.62	0.67	0.71

Sources: Oklahoma DOT
Calculations: EBP

Based on these data, combined with annual vehicle miles traveled (VMT) measured across the project, crash rates were calculated (crashes per million VMT) and applied to ODOT's estimates of project-wide VMT in the future. A baseline of total anticipated crashes without the I-44 and US-75 Corridor Improvement Projects was then calculated for the entire project horizon of 25 years, through the year 2050. Next, the FHWA's Crash Modification Factor (CMF) database was consulted to obtain the most applicable Crash Reduction Factor (CRF). This search yielded a most relevant CMF of 55 percent (and thus a CRF of 45 percent). The selected CMF/CRF is obtained from research involving the safety effects of replacing cloverleaf interchanges with directional lanes. The relevant CMF was then applied to the future stream of No-Build crashes (by category of severity) to obtain estimates of reduced annual crashes over the study period.

The Project will generate significant savings in the human costs of crashes. Over the 25 years, it is estimated that about 15 lives will be saved, and another 77 serious injury-crashes will be avoided.

Travel Delay Savings: ODOT provided an analysis of travel delay reductions based on the application of the VISSIM traffic simulation model to a future 2045 build year. The model simulated the effects of The Project on travel times. Based on estimates provided by ODOT, the BCA analysis assumes that 75 percent of the total travel delay reductions due to the entire I-44 and US-75 corridor improvements can be attributed to WPs 2, 3, and 5. Travel delay savings for years before 2045 were reduced based on the anticipated compound annual growth rates (CAGR) in VMT projected for the corridor of about 1.36 percent per year. For the years after 2045, the delay was correspondingly increased by the same CAGR. In 2030, approximately 933 hours of travel delay would be saved by The Project each workday, covering morning and evening peak periods combined. Travel delay savings increases to approximately 1,075 hours of delay per workday in 2045.

Table 3 presents the outputs of the VISSIM run.

Table 4 presents the computations to derive the annual travel delay for trucks (vehicle hours of delay) and passenger (passenger hours of delay). These savings were monetized utilizing the values of time prescribed in the 2022 USDOT BCA guidance.

Table 3. VISSIM travel delay outputs, Build and No-Build

AM Period	Delay (Seconds)			
	All	Auto	Single Axle Truck	Multi-Axle Truck
2045 AM - No Action	4,048,058	3,672,981	136,664	238,412
Ult Build AM 2045	2,458,430	2,295,220	75,521	87,690
PM Period	**Delay (Seconds)**			
	All	Auto	Single Axle Truck	Multi-Axle Truck
2045 PM - No Action	5,247,408	4,756,955	189,138	301,314
Ult Build PM 2045	1,108,531	999,481	43,956	65,094

Source: Garver Engineering and ODOT

Table 4. Travel delay calculations

Daily Vehicle Hours	2025	2030	2035	2040	2045	2050
Auto	814	871	933	999	1,070	1,145
Single Axle Truck	33	35	37	40	43	46
Multi-Axle Truck	61	66	70	75	81	86
Annual Vehicle Hours	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Auto	203,386	217,799	233,233	249,761	267,460	286,149
Single Axle Truck	8,172	8,751	9,371	10,035	10,746	11,497
Multi-Axle Truck	15,325	16,411	17,574	18,820	20,153	21,561
Annual passenger hours saved	**301,011**	**322,342**	**345,185**	**369,646**	**395,841**	**423,500**

Source: EBP
Notes: Delay savings attributable to Work Packages 2,3, and 5 equal 75% of total project-wide VISSIM results. Delay savings for years other than 2045 based on CAGR for project VMT. Delay savings reduced for years prior to 2045 by compound growth factor of (1 - CAGR).

Air Emissions Reductions: No significant changes in VMT are anticipated as a result of The Project and therefore emissions savings were estimated based upon delay reductions for passenger cars and light trucks, medium-duty trucks, and heavy-duty trucks. The emissions factors were extracted from the TREDIS model, which were derived from a national-level analysis using the EPA's MOVES model. MOVES default model year distributions were used for each evaluation year, and default rural/urban restricted/unrestricted activity distributions were used. Running, starting, and extended idle (including crankcase) emissions processes were all included and aggregated. The emissions factors displayed in Table 5 are scaled up by a factor of 10^6 for easier reading and are converted to the appropriate units in the accompanying benefit cost model.

The estimates in emissions reduction are based on per-ton valuations for the type of emissions as outlined in the 2022 US DOT BCA Guidance. Emissions include carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxide (SO_x), volatile organic compounds (VOC), and particulate matter (PM 2.5). The cost of carbon was discounted at 3% while all other emissions were discounted at 7%. VOCs were included as VOCs are a precursor to ozone which is recognized as having serious health impacts and monetized using prior USDOT valuation guidance and adjusted to 2020 dollars. If VOCs are removed, the benefit cost ratio remains at 1.2 as the aggregate impact of the VOC estimates are an undiscounted $105,700 over the 25-year benefit period.

Based on air emission rates, combined with the travel delay reductions, annual emissions reductions were calculated and monetized. The Project will reduce CO2 emissions by 5.023 tons a year through reduced congestion. (see Table 6).

Table 5. Air emissions rates per hour of travel delay in Tons multiplied by 10^6.

	Co2	VOC	NOx	PM2.5	SOx
Car	12,884.90	4.96	7.79	0.37	0.08
Light Truck	40,664.22	6.83	64.33	2.99	0.34
Heavy Truck	76,946.75	19.88	241.78	7.17	0.68

Source: MOVES Emissions factors from TREDIS

Table 6. Aggregate Emissions Savings 2027-2051

	Total	Average Annual	Undiscounted $
Co2	125,580.28	5,023.21	$9,151,720
VOC	41.60	1.66	$99,178
NOx	176.74	7.07	$3,186,263
PM2.5	6.35	0.25	$5,494,839
SOx	0.92	0.04	$44,932
Total (excluding CO2)	n/a	n/a	$8,825,212
Total (all emissions)			$17,976,932

Source: EBP

Shipper and Logistics Cost Savings: Shipper and logistics cost savings are based on Freight Analysis Framework (FAF) Tulsa FAF region for 2020, truck travel delay savings, and data from the TREDIS-based Multimodal Benefit Cost Analysis (MBCA) tool. The FAF data were used to develop a commodity mix breakdown of the trucking data (see Table 7), and the commodity mixes were cross-referenced to Standard Classification of Transportation Goods (SCTG) data. These values are then applied to the truck travel delay savings to derive ton hours saved by commodity type and SCTG category. Ton hours saved are then multiplied by the hourly value of shipper delay for each commodity (hourly values are obtained from the TREDIS-based MBCA model). Costs are summed across all commodity types to derive the annual savings (see Table 8).

Table 7. Freight vehicle commodity mix breakout (Tulsa)

SCTG2	SCTG Description	Truck-Commodity Mix
1	Live animals/fish	0.3%
2	Cereal grains	2.7%
3	Other ag prods.	0.5%
4	Animal feed	0.6%
5	Meat/seafood	0.3%
6	Milled grain prods.	0.8%
7	Other foodstuffs	3.0%
8	Alcoholic beverages	0.3%
9	Tobacco prods.	0.0%
10	Building stone	0.0%
11	Natural sands	0.3%
12	Gravel	0.4%
13	Nonmetallic minerals	1.1%
14	Metallic ores	0.6%
15	Coal	0.0%
16	Crude petroleum	0.0%
17	Gasoline	2.2%
18	Fuel oils	1.4%
19	Coal-n.e.c.	50.0%
20	Basic chemicals	1.2%
21	Pharmaceuticals	0.0%
22	Fertilizers	7.8%
23	Chemical prods.	0.5%
24	Plastics/rubber	1.0%
25	Logs	0.0%
26	Wood prods.	1.4%
27	Newsprint/paper	0.3%
28	Paper articles	1.7%
29	Printed prods.	0.3%
30	Textiles/leather	0.2%
31	Nonmetal min. prods.	6.4%
32	Baseline metals	5.3%
33	Articles-Baseline metal	2.5%
34	Machinery	1.7%
35	Electronics	0.9%
36	Motorized vehicles	0.8%
37	Transport equip.	0.1%
38	Precision instruments	0.0%
39	Furniture	0.4%
40	Misc. mfg. prods.	0.8%
41	Waste/scrap	0.3%
43	Mixed freight	1.8%
99	Unknown	0.0%

Source: Tulsa FAF Region (2020)

Table 8. Calculation of shipper benefits for selected years

SCTG2	SCTG Description	2025	2030	2035	2040	2045	2050
1	Live animals/fish	$2,938	$3,146	$3,369	$3,608	$3,863	$4,133
2	Cereal grains	$9,333	$9,994	$10,702	$11,461	$12,273	$13,130
3	Other ag prods.	$2,516	$2,694	$2,885	$3,090	$3,309	$3,540
4	Animal feed	$2,881	$3,085	$3,304	$3,538	$3,788	$4,053
5	Meat/seafood	$3,258	$3,489	$3,736	$4,001	$4,284	$4,583
6	Milled grain prods.	$4,618	$4,945	$5,296	$5,671	$6,073	$6,497
7	Other foodstuffs	$20,202	$21,633	$23,166	$24,808	$26,566	$28,422
8	Alcoholic beverages	$2,588	$2,772	$2,968	$3,179	$3,404	$3,642
9	Tobacco prods.	$27	$29	$31	$33	$36	$38
10	Building stone	$60	$64	$69	$74	$79	$84
11	Natural sands	$300	$322	$344	$369	$395	$423
12	Gravel	$391	$419	$449	$480	$515	$550
13	Nonmetallic minerals	$2,929	$3,137	$3,359	$3,597	$3,852	$4,121
14	Metallic ores	$766	$820	$878	$941	$1,007	$1,078
15	Coal	$20	$22	$23	$25	$26	$28
16	Crude petroleum	$158	$169	$181	$194	$208	$222
17	Gasoline	$10,126	$10,844	$11,612	$12,435	$13,317	$14,247
18	Fuel oils	$5,374	$5,754	$6,162	$6,599	$7,066	$7,560
19	Coal-n.e.c.	$208,345	$223,109	$238,919	$255,850	$273,981	$293,126
20	Basic chemicals	$6,996	$7,491	$8,022	$8,591	$9,199	$9,842
21	Pharmaceuticals	$849	$910	$974	$1,043	$1,117	$1,195
22	Fertilizers	$24,909	$26,674	$28,564	$30,588	$32,756	$35,045
23	Chemical prods.	$5,635	$6,034	$6,462	$6,920	$7,410	$7,928
24	Plastics/rubber	$10,753	$11,515	$12,331	$13,205	$14,141	$15,129
25	Logs	$139	$149	$159	$171	$183	$196
26	Wood prods.	$8,842	$9,469	$10,140	$10,858	$11,628	$12,440
27	Newsprint/paper	$2,725	$2,919	$3,125	$3,347	$3,584	$3,835
28	Paper articles	$14,654	$15,692	$16,804	$17,995	$19,270	$20,617
29	Printed prods.	$2,256	$2,416	$2,587	$2,771	$2,967	$3,174
30	Textiles/leather	$2,130	$2,281	$2,442	$2,615	$2,801	$2,996
31	Nonmetal min. prods.	$27,590	$29,545	$31,639	$33,881	$36,282	$38,817
32	Baseline metals	$36,646	$39,243	$42,024	$45,002	$48,191	$51,559
33	Articles-Baseline metals	$21,977	$23,534	$25,202	$26,988	$28,900	$30,919
34	Machinery	$44,806	$47,982	$51,382	$55,023	$58,922	$63,039
35	Electronics	$23,938	$25,635	$27,451	$29,397	$31,480	$33,680
36	Motorized vehicles	$21,360	$22,873	$24,494	$26,230	$28,089	$30,052
37	Transport equip.	$1,368	$1,465	$1,568	$1,680	$1,799	$1,924
38	Precision instruments	$1,387	$1,485	$1,590	$1,703	$1,824	$1,951
39	Furniture	$4,735	$5,070	$5,429	$5,814	$6,226	$6,661
40	Misc. mfg. prods.	$14,064	$15,061	$16,128	$17,271	$18,495	$19,788
41	Waste/scrap	$2,131	$2,282	$2,444	$2,617	$2,802	$2,998
43	Mixed freight	$11,675	$12,503	$13,389	$14,337	$15,353	$16,426
99	Unknown	$0	$0	$0	$0	$0	$0
Total		**$568,395**	**$608,674**	**$651,808**	**$697,998**	**$747,461**	**$799,690**

Source: EBP

3.2. Project Benefits Not Included in the BCA

Due to time and data limitations, the analysis does not include all secondary benefits of reduced congestion, over and above the estimated reduction in travel delay itself. Severe bottlenecks and driving under highly congested conditions, which characterize several of the ramp and ramp approach roadways of the interchange, generally introduce significant unreliability into travel decision making, often necessitating drivers build in added buffer time to their trips.

No significant changes in VMT are anticipated as a result of The Project; accordingly, there are no changes in vehicle operating and maintenance costs measured for BCA purposes.

4. BCA Results

Based on the assumptions, methodology, and other information presented above, the project yields a Benefit Cost Ratio of 1.22 and a Net Present Value of $30.8 million. The results are summarized in Table 9. Crash reductions comprise 60 percent of the total monetized benefits, followed by travel delay savings representing 33 percent, emissions at 4.6 percent, and shipper cost savings at 3 percent of total benefits. Additionally, two categories of freight benefits were measured: shipper and supply chain cost savings and truck travel time reductions. The present value of the two freight categories are $18 million, or 10.7 percent of total project benefits.

Table 9. BCA Results

Benefit Cost	**Amount**
Discounted Initial Capital Costs	$148.4
Discounted Life Cycle Cost Savings	-$11.3
Facilities Residual Value	$0.0
Total Discounted Costs	**$137.1**
Crash Reductions Benefits	$100.0
Travel Delay Cost Savings	$55.1
Emissions Reduction Benefits (CO_2 at a 3% discount rate)	$5.1
Emissions Reduction Benefits (all others at a 7% discount rate)	$2.6
Shipper/Supply Chain Cost Savings	$5.1
Total Discounted Benefits	**$168.0**
Benefit Cost Ratio	**1.22**
Net Present Value ($M)	**$30.8**

Source: EBP