Benefit-Cost Analysis Supplementary Documentation

Competitive Highway Bridge Program

County Bridge Replacement, Grant County, Oklahoma

Oklahoma Department of Transportation

December 4, 2018

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Executive Summary

Oklahoma Department of Transportation (ODOT) is seeking grant funding through the Competitive Highway Bridge Program to improve 34 structurally deficient bridges. A Benefit-Cost Analysis (BCA) of this project accounts for the costs and benefits of the proposed investment over a 35-year period. This period of analysis includes about 4.5 years of planning, design and construction and 30 years of operation. The total project cost to construct these 34 bridges is $10.3 million and is proposed for financing from Federal, State, and County funds. This cost estimate reflects an approximately 12 percent savings below $11.6 million, the total cost if each bridge was constructed separately.

Table ES-1 shows that the present value of benefits exceed costs overall – a result that indicates the overall project is economically worthwhile. Altogether, the project is expected to generate $23.6 million in discounted benefits and yielding $14.8 million in discounted net benefits. The benefit-cost ratio indicates that the project generates $2.83 in value for every $1 invested. Table ES-2 and Table ES-3 provide additional details on the results over time and as a summary of benefit categories per individual bridge. As indicated, the value of most bridges individually also exceeds their respective costs.

Table ES-1: Total Benefits and Costs ($2018 thousands)

Items		Total Discounted Value (7%) (thousands of $)	Total Discounted Value (3%) (thousands of $)
Costs			
	Capital Cost	$8,098.6	$9,249.0
	O&M Cost	$731.0	$1,658.9
	Total	**$8,829.7**	**$9,249.0**
Benefits			
	Existing Bridge O&M Cost Savings	$804.9	$1,218.5
	Residual Value of Capital Improvement Investment	$717.7	$2,774.2
	Time Savings	$6,513.3	$13,378.0
	Crash Risk Reduction	$8,293.6	$17,344.7
	Pavement Damage Reduction	$268.2	$517.4
	Fuel Cost Savings	$6,886.7	$13,550.1
	Emissions Cost Reduction	$166.8	$292.5
	Total	**$23,651.2**	**$49,075.4**
NPV		**$14,821.5**	**$39,826.4**
BCR		**2.83**	**5.13**

Table ES-2: Summary of Travel Volumes, Benefits and Costs ($2018 thousands)

Calendar Year	Year	Annual Avoided Truck VMT	Annual Avoided Auto VMT	Annual Avoided Truck VHT	Annual Avoided Auto VHT	Undiscounted Individual Projects Capital Costs	Undiscounted Bundled Projects Capital and O&M Costs	Discounted Bundled Costs at 7%	Undiscounted Benefits	Discounted Benefits at 7%	Undiscounted Bundled Net Benefits	Discounted Bundled Net Benefits at 7%
2019	1	0	0	0	0	$1,345	$1,186	$1,109	$0	$0	($1,186)	($1,109)
2020	2	0	0	0	0	$1,345	$1,186	$1,036	$0	$0	($1,186)	($1,036)
2021	3	0	0	0	0	$1,345	$1,186	$968	$0	$0	($1,186)	($968)
2022	4	0	0	0	0	$4,543	$4,008	$3,057	$142	$109	($3,865)	($2,949)
2023	5	53,605	228,430	1,191	5,076	$3,066	$2,705	$1,928	$820	$585	($1,884)	($1,344)
2024	6	167,272	712,743	3,717	15,839	$0	$0	$0	$1,661	$1,107	$1,661	$1,107
2025	7	174,828	807,745	3,885	17,950	$0	$0	$0	$1,775	$1,105	$1,775	$1,105
2026	8	177,302	861,721	3,940	19,149	$0	$0	$0	$1,834	$1,067	$1,834	$1,067
2027	9	179,777	873,686	3,995	19,415	$68	$68	$37	$1,864	$1,014	$1,796	$977
2028	10	187,625	885,651	4,169	19,681	$68	$68	$35	$1,915	$973	$1,847	$939
2029	11	190,172	942,423	4,226	20,943	$68	$68	$32	$2,122	$1,008	$2,054	$976
2030	12	192,720	1,317,796	4,283	29,284	$68	$68	$30	$2,439	$1,083	$2,371	$1,053
2031	13	195,268	1,335,141	4,339	29,670	$68	$68	$28	$2,474	$1,027	$2,406	$998
2032	14	197,815	1,352,486	4,396	30,055	$68	$68	$26	$2,510	$973	$2,442	$947
2033	15	200,363	1,369,830	4,453	30,441	$68	$68	$25	$2,546	$923	$2,478	$898
2034	16	202,911	1,387,175	4,509	30,826	$119	$119	$40	$2,658	$900	$2,539	$860
2035	17	205,459	1,596,218	4,566	35,472	$119	$119	$38	$2,861	$906	$2,742	$868
2036	18	208,006	1,615,928	4,622	35,910	$119	$119	$35	$2,902	$859	$2,783	$823
2037	19	210,554	1,635,638	4,679	36,348	$119	$119	$33	$2,943	$814	$2,824	$781
2038	20	213,102	1,655,348	4,736	36,786	$119	$119	$31	$2,984	$771	$2,865	$740
2039	21	215,649	1,675,058	4,792	37,224	$119	$119	$29	$3,046	$736	$2,927	$707
2040	22	218,197	1,746,160	4,849	38,804	$119	$119	$27	$3,131	$707	$3,012	$680
2041	23	220,745	1,766,469	4,905	39,255	$119	$119	$25	$3,174	$670	$3,055	$644
2042	24	223,292	1,786,777	4,962	39,706	$119	$119	$23	$3,217	$634	$3,098	$611
2043	25	225,840	1,807,086	5,019	40,157	$119	$119	$22	$3,261	$601	$3,142	$579

Calendar Year	Year	Annual Avoided Truck VMT	Annual Avoided Auto VMT	Annual Avoided Truck VHT	Annual Avoided Auto VHT	Undiscounted Individual Projects Capital Costs	Undiscounted Bundled Projects Capital and O&M Costs	Discounted Bundled Costs at 7%	Undiscounted Benefits	Discounted Benefits at 7%	Undiscounted Bundled Net Benefits	Discounted Bundled Net Benefits at 7%
2044	26	228,388	1,827,394	5,075	40,609	$170	$170	$29	$3,305	$569	$3,135	$540
2045	27	230,936	1,847,703	5,132	41,060	$170	$170	$27	$3,371	$543	$3,201	$515
2046	28	233,483	1,922,440	5,189	42,721	$170	$170	$26	$3,464	$521	$3,294	$495
2047	29	236,031	1,943,340	5,245	43,185	$170	$170	$24	$3,510	$493	$3,340	$470
2048	30	238,579	1,964,240	5,302	43,650	$170	$170	$22	$3,557	$467	$3,387	$445
2049	31	241,126	1,985,140	5,358	44,114	$170	$170	$21	$3,603	$442	$3,433	$422
2050	32	243,674	2,006,040	5,415	44,579	$170	$170	$20	$3,651	$419	$3,481	$399
2051	33	246,222	2,026,940	5,472	45,043	$170	$170	$18	$3,698	$397	$3,528	$378
2052	34	248,769	2,047,840	5,528	45,508	$170	$170	$17	$3,400	$341	$3,230	$324
2053	35	169,605	1,396,117	3,769	31,025	$115	$115	$11	$5,796	$543	$5,681	$532
2054									$3,961	$347	$3,961	$347
Total		**6,377,315**	**46,326,703**	**141,718**	**1,029,482**	**$14,954**	**$13,582**	**$8,830**	**$93,593**	**$23,651**	**$80,012**	**$14,821**

Table ES-3: Benefit-Cost Analysis Summary by Bridge

ID (NBI)	Status	Closure Year	NPV	Costs	Benefits	Rank of NPV	Capital Cost	O&M Cost	Residual Value	Time Savings	Crash Risk Reduction	Reduced Pavement Damage	Fuel Cost	Emissions Cost	Existing O&M Cost Savings
4244	E	2020	$857	$232	$1,090	1	$211	$22	$19	$318	$400	$12	$333	$8	$0
4305	E	2019	$717	$247	$964	3	$225	$22	$20	$224	$476	$7	$232	$5	$0
10177	P	2025	$479	$247	$727	19	$226	$22	$20	$209	$260	$7	$218	$5	$8
10228	E	2019	$813	$281	$1,095	2	$260	$22	$23	$318	$400	$12	$333	$8	$0
10799	P	2025	$481	$245	$727	18	$224	$22	$20	$209	$260	$7	$218	$5	$8
10991	E	2026	$434	$247	$681	20	$226	$22	$20	$193	$243	$7	$201	$4	$13
11146	P	2030	$331	$259	$590	25	$237	$22	$21	$156	$193	$7	$167	$4	$40
11151	P	2030	$334	$253	$587	23	$231	$22	$20	$155	$193	$7	$166	$4	$40
11162	P	2030	$334	$246	$580	22	$225	$22	$20	$156	$193	$7	$167	$4	$32
11461	E	2021	$518	$251	$769	10	$229	$22	$20	$224	$280	$7	$232	$5	$0
11471	E	2020	$521	$247	$768	8	$226	$22	$20	$224	$280	$7	$232	$5	$0
11486	K	2010	$516	$253	$769	11	$232	$22	$21	$224	$280	$7	$232	$5	$0
11503	E	2019	$666	$245	$912	4	$224	$22	$20	$267	$335	$9	$276	$6	$0
11514	A	2030	$333	$248	$581	24	$226	$22	$20	$156	$193	$7	$167	$4	$32
11518	P	2030	$335	$245	$580	21	$224	$22	$20	$156	$193	$7	$167	$4	$32
11641	A	2030	$311	$281	$592	29	$259	$22	$23	$156	$193	$7	$167	$4	$40
11818	E	2019	$494	$277	$771	16	$255	$22	$23	$224	$280	$7	$232	$5	$0
11820	K	2013	$488	$284	$772	17	$262	$22	$23	$224	$280	$7	$232	$5	$0
11824	E	2019	$501	$269	$770	15	$247	$22	$22	$224	$280	$7	$232	$5	$0
11841	P	2030	$321	$270	$591	28	$248	$22	$22	$156	$193	$7	$167	$4	$40
11844	E	2021	$519	$254	$773	9	$232	$22	$21	$226	$280	$7	$234	$5	$0
11849	E	2019	$502	$272	$774	14	$251	$22	$22	$226	$280	$7	$234	$5	$0
11863	E	2022	$507	$266	$774	12	$245	$22	$22	$226	$280	$7	$234	$5	$0
13281	P	2035	$218	$263	$480	30	$241	$22	$21	$115	$142	$7	$129	$4	$62
13327	P	2035	$213	$268	$481	31	$247	$22	$22	$115	$142	$7	$129	$4	$62
13330	P	2035	$603	$269	$872	6	$248	$22	$22	$228	$283	$15	$255	$8	$62
14529	E	2029	$327	$249	$576	26	$227	$22	$20	$157	$198	$7	$163	$3	$28

ID (NBI)	Status	Closure Year	NPV	Costs	Benefits	Rank of NPV	Capital Cost	O&M Cost	Residual Value	Time Savings	Crash Risk Reduction	Reduced Pavement Damage	Fuel Cost	Emissions Cost	Existing O&M Cost Savings
14739	P	2040	$127	$269	$395	32	$247	$22	$22	$85	$101	$7	$100	$4	$77
21824	E	2022	$647	$266	$914	5	$245	$22	$22	$267	$335	$9	$276	$6	$0
22742	A	2030	$324	$266	$590	27	$245	$22	$22	$156	$193	$7	$167	$4	$40
23382	E	2019	$523	$249	$772	7	$227	$22	$20	$226	$280	$7	$234	$5	$0
23446	A	2073	-$35	$284	$250	34	$263	$22	$23	$34	$30	$7	$51	$4	$100
24832	P	2046	$57	$259	$317	33	$238	$22	$21	$57	$64	$7	$74	$4	$90
25184	P	2021	$505	$265	$770	13	$244	$22	$22	$224	$280	$7	$232	$5	$0
Total			**$14,821**	**$8,830**	**$23,651**		**$8,099**	**$731**	**$718**	**$6,513**	**$8,294**	**$268**	**$6,887**	**$167**	**$805**

1 Introduction

This document provides detailed technical information on the Benefit-Cost Analysis (BCA) conducted in support of the Competitive Highway Bridge Program (CHBP) grant application for the County Bridge Replacement Program for Grant County.

The BCA accounts for the monetized benefits and costs using standard methods and many economic parameters established through guidance from USDOT. As background, a BCA estimates anticipated benefits that are generated by a project over a specified period of time and compares them to a project's costs. 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 the monetized value of the impacts of a project on both users and non-users of a roadway.[1]

The methodology developed to analyze this project is consistent with BCA guidance provided by USDOT and with the CHBP guidelines. The methodology involves:

- Establishing existing and future conditions under the build and no-build scenarios;
- Assessing benefits that align with those identified in the BCA guidance;
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;
- Using USDOT guidance for the valuation of travel time savings, safety benefits and reductions in air emissions, and relying on best practices for valuing other impacts;
- Discounting future benefits and costs utilizing the 7 percent real discount rate recommended by USDOT; and
- Conducting a sensitivity analysis to assess the impacts of changes to key parameters.

This document is organized in several sections, as follows. Section 2 provides an overview of the project, including a brief description of existing conditions and proposed alternatives; a summary of cost estimates and schedule; and a description of the types of effects from the project; and estimates of travel demand and traffic growth. Section 3 discusses data elements and assumptions pertaining to the economic benefits generated by the project. Estimates of the project's Net Present Value (NPV), its Benefit-Cost Ratio (BCR) and other project evaluation metrics are presented in Section 4. Section 5 provides the outcomes of a sensitivity analysis that is conducted to assess the robustness of the results. Full details of annual benefits and costs are found in the Microsoft Excel file that is also included as part of this application package.

[1] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, June 2018.

2 Project Overview

2.1 Base Case

The analysis of benefits and costs considers a comparison of a single no-build 'base case' and single build scenario. The no-build scenario reflects the continuation of current conditions, which in some cases includes the anticipated closure of bridges during the analytical period, that is, within the next 35 years. Operations and maintenance costs are incurred while a bridge is open and no major infrastructure temporary improvements are assumed to occur to keep a bridge from closing. Table 1 provides current information on the type of construction, operating status, the year originally constructed, and the years in which it will (or was) posted for weight limits and when it would close for all vehicles. The years of load posting and closure are provided by the County Commissioners responsible for maintaining bridges. According to current operating status, an Open Condition ("A" or "E") means that all vehicles can use the bridge. However, if the bridge is "Posted For Load" ("P"), trucks would take a detour around the bridge. Of course, if the bridge is closed ("K"), all vehicles would detour around the bridge.

Table 1: Current Bridge Characteristics – Base Case

ID	General Description	Operating Status Code	Operating Status Description	Year Built	Year of Posting for Load	Year of Closure
4244	21FT. TIMBER SPAN, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1935	2019	2020
4305	25FT. TIMBER SPAN, TEMP STEEL PIPE	E	OPEN, TEMP. STRUCTURE	1935	2018	2019
10177	25FT. TIMBER SPAN	P	POSTED FOR LOAD	1945	2019	2025
10228	18FT.-15FT. TIMBER SPANS, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1945	2018	2019
10799	25FT. TIMBER SPAN	P	POSTED FOR LOAD	1945	2010	2025
10991	25FT. TIMBER SPAN, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1949	2025	2026
11146	26FT. I-BEAM SPAN	P	POSTED FOR LOAD	1950	2015	2030
11151	26FT. TIMBER SPAN	P	POSTED FOR LOAD	1950	2015	2030
11162	25FT. TIMBER SPAN	P	POSTED FOR LOAD	1950	2015	2030
11461	25FT. TIMBER SPAN, TEMP PIPES	E	OPEN, TEMP. STRUCTURE	1950	2020	2021
11471	24FT. TIMBER SPAN, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1950	2019	2020
11486	26FT. TIMBER SPAN	K	CLOSED TO ALL TRAFFIC	1950	1995	2010
11503	24FT. TIMBER SPAN, TEMP PIPES	E	OPEN, TEMP. STRUCTURE	1950	2018	2019
11514	24FT. I-BEAM SPAN	A	OPEN, NO RESTRICTION	1950	2019	2030
11518	24FT. I-BEAM SPAN	P	POSTED FOR LOAD	1950	2015	2030
11641	31FT. I-BEAM SPAN	A	OPEN, NO RESTRICTION	1950	2019	2030
11818	19FT. TIMBER SPAN, 3 TEMP PIPES	E	OPEN, TEMP. STRUCTURE	1950	2018	2019
11820	15FT., 20FT. TIMBER SPANS	K	CLOSED TO ALL TRAFFIC	1950	1998	2013
11824	2-15FT. TIMBER SPAN, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1950	2018	2019
11841	2-15FT. TIMBER SPANS	P	POSTED FOR LOAD	1950	2015	2030
11844	27FT. TIMBER SPAN, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1950	2020	2021
11849	2-15FT. TIMBER SPANS, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1950	2018	2019
11863	30FT. TIMBER/I-BEAM SPAN TEMP PIPES	E	OPEN, TEMP. STRUCTURE	1950	2021	2022

ID	General Description	Operating Status Code	Operating Status Description	Year Built	Year of Posting for Load	Year of Closure
13281	29FT. TIMBER SPAN	P	POSTED FOR LOAD	1955	2019	2035
13327	30FT. TIMBER SPAN	P	POSTED FOR LOAD	1955	2019	2035
13330	31FT. I-BEAM SPAN	P	POSTED FOR LOAD	1955	2019	2035
14529	25FT. TIMBER SPAN, TEMP PIPES	E	OPEN, TEMP. STRUCTURE	1960	2028	2029
14739	31FT. I-BEAM SPAN	P	POSTED FOR LOAD	1960	2019	2040
21824	TEMP PIPES	E	OPEN, TEMP. STRUCTURE	1988	2021	2022
22742	30FT. I-BEAM SPAN	A	OPEN, NO RESTRICTION	1950	2019	2030
23382	25FT. TIMBER SPAN, TEMP PIPE	E	OPEN, TEMP. STRUCTURE	1940	2018	2019
23446	3-9FT. X 40FT. TANK CARS	A	OPEN, NO RESTRICTION	1993	2019	2073
24832	28FT. DBL RR FLATCAR SPAN	P	POSTED FOR LOAD	1996	2019	2046
25184	30FT. DBL RR FLATCAR SPAN	P	POSTED FOR LOAD	1941	2006	2021

2.2 Project Cost and Schedule – Build Scenario

The build scenario assumes that each of the 34 individual bridges will be constructed as planned, and the improvements enable motorists to avoid detours to reach their destination. The total project cost is $11.6 million if the bridges are constructed independently. When bundled in one contract, total capital costs decrease by about 12 percent to $10.3 million (Table 2).

Table 2: Estimated Construction and O&M Costs of Improved Bridges

ID	Current Bridge Length (FT)	Pre-Construction Cost (thousands of $)	Construction and Inspection Cost (thousands of $)	Total Capital Cost (thousands of $)	Total 30-year O&M Cost (thousands of $)	Total 30-year Lifecycle Cost (thousands of $)
4244	21.0	$102.0	$163.6	$265.6	$97.4	$362.9
4305	24.9	$103.3	$181.9	$285.2	$97.4	$382.6
10177	25.0	$103.3	$182.4	$285.7	$97.4	$383.1
10228	34.0	$106.3	$224.7	$331.0	$97.4	$428.4
10799	24.5	$103.2	$180.0	$283.2	$97.4	$380.6
10991	25.0	$103.3	$182.4	$285.7	$97.4	$383.1
11146	28.0	$104.3	$196.5	$300.8	$97.4	$398.2
11151	26.4	$103.8	$188.9	$292.7	$97.4	$390.1
11162	24.7	$103.2	$180.9	$284.2	$97.4	$381.6
11461	25.9	$103.6	$186.6	$290.2	$97.4	$387.6
11471	24.9	$103.3	$182.0	$285.4	$97.4	$382.7
11486	26.6	$103.9	$189.9	$293.8	$97.4	$391.1
11503	23.9	$105.2	$177.4	$282.6	$97.4	$380.0
11514	24.7	$105.2	$180.9	$286.2	$97.4	$383.5
11518	24.0	$105.2	$177.6	$282.9	$97.4	$380.2
11641	34.1	$105.2	$225.1	$330.4	$97.4	$427.7
11818	33.0	$105.2	$220.0	$325.2	$97.4	$422.5
11820	35.0	$105.2	$229.4	$334.6	$97.4	$432.0

ID	Current Bridge Length (FT)	Pre-Construction Cost (thousands of $)	Construction and Inspection Cost (thousands of $)	Total Capital Cost (thousands of $)	Total 30-year O&M Cost (thousands of $)	Total 30-year Lifecycle Cost (thousands of $)
11824	30.7	$105.2	$209.1	$314.4	$97.4	$411.7
11841	31.0	$105.2	$210.6	$315.8	$97.4	$413.2
11844	26.4	$105.2	$188.9	$294.2	$97.4	$391.5
11849	31.7	$105.2	$213.8	$319.1	$97.4	$416.4
11863	30.0	$105.2	$205.9	$311.1	$97.4	$408.4
13281	28.9	$105.2	$200.7	$305.9	$97.4	$403.3
13327	30.5	$105.2	$208.2	$313.4	$97.4	$410.8
13330	30.8	$105.2	$209.6	$314.8	$97.4	$412.2
14529	25.0	$105.2	$182.4	$287.6	$97.4	$384.9
14739	30.6	$105.2	$208.7	$313.9	$97.4	$411.3
21824	30.0	$105.2	$205.9	$311.1	$97.4	$408.4
22742	30.0	$105.2	$205.9	$311.1	$97.4	$408.4
23382	25.0	$105.2	$182.4	$287.6	$97.4	$384.9
23446	35.1	$105.2	$229.9	$335.1	$97.4	$432.4
24832	27.9	$105.2	$196.0	$301.2	$97.4	$398.6
25184	29.7	$105.2	$204.5	$309.7	$97.4	$407.0
Total		**$3,558.4**	**$6,712.4**	**$10,270.8**	**$3,310.7**	**$13,581.5**

As indicated in Table 3, pre-construction and construction activities will occur from 2019 through 2023. It is anticipated that bridges will take approximately 23 months to construct. It is assumed that the bridges will all be open for service upon construction completion in 2023. Because of the long, useful life of bridge infrastructure (assumed to be 70 years), an analysis period of 30 years was utilized for this BCA. Residual value of bridge costs are technically a cost adjustment, but included with project benefits in the numerator of the BCR. Residual value is computed and included partly in year 2053 and 2054. In addition, net O&M costs are also included in the numerator of the BCR, as per USDOT guidance.

Table 3: Basic Planning Schedule

Task Name	Start	Finish	Months
Initiation	07/01/19	07/22/19	0.7
Design	07/23/19	06/27/21	23.2
Environmental Document	07/23/19	05/01/20	9.3
Right Of Way Process	02/17/21	06/17/21	3.9
Bid Award Process	06/28/21	10/16/21	3.6
Construction	10/17/21	09/06/23	22.7

2.3 Demand Projections

The traffic forecast is a critical component of the benefit-cost analysis since most of the benefits depend on the change in vehicle travel distance between the baseline and build scenarios. ODOT prepared travel demand forecasts of passenger vehicles and trucks for each bridge for

both the no-build and build scenarios. These forecasts are quantified as average daily travel (ADT) demands that are annualized with 365 days per year. Depending on the usability of the bridge, the passenger vehicle and truck ADT values represent the volumes that *use* the bridge if it is open, or alternatively, the volume that *would* use the bridge it were not. The increase in ADT volumes in the build scenario is due to improved roadway conditions. Table 4 presents total ADT for the number of passenger vehicles and trucks for each bridge in selected years. The number of trucks is separately estimated for each bridge and is about 11%, on average. Estimated benefits are computed separately for passenger vehicle and trucks based on their ADTs.

Table 4: Travel Demand Forecasts – Combined Passenger Vehicles and Trucks

	Existing ADT			Build ADT		
ID	2020	2030	2040	2020	2030	2040
4244	81.6	89.6	97.6	88.0	105.6	123.2
4305	57.1	62.7	68.3	63.0	75.6	88.2
10177	57.1	62.7	68.3	64.0	76.8	89.6
10228	81.6	89.6	97.6	88.0	105.6	123.2
10799	57.1	62.7	68.3	64.0	76.8	89.6
10991	57.1	62.7	68.3	63.0	75.6	88.2
11146	57.1	62.7	68.3	64.0	76.8	89.6
11151	57.1	62.7	68.3	63.0	75.6	88.2
11162	57.1	62.7	68.3	64.0	76.8	89.6
11461	57.1	62.7	68.3	63.0	75.6	88.2
11471	57.1	62.7	68.3	63.0	75.6	88.2
11486	57.1	62.7	68.3	63.0	75.6	88.2
11503	68.3	75.0	81.7	75.0	90.0	105.0
11514	57.1	62.7	68.3	64.0	76.8	89.6
11518	57.1	62.7	68.3	64.0	76.8	89.6
11641	57.1	62.7	68.3	64.0	76.8	89.6
11818	57.1	62.7	68.3	63.0	75.6	88.2
11820	57.1	62.7	68.3	63.0	75.6	88.2
11824	57.1	62.7	68.3	63.0	75.6	88.2
11841	57.1	62.7	68.3	64.0	76.8	89.6
11844	57.1	62.7	68.3	64.0	76.8	89.6
11849	57.1	62.7	68.3	64.0	76.8	89.6
11863	57.1	62.7	68.3	64.0	76.8	89.6
13281	57.1	62.7	68.3	64.0	76.8	89.6
13327	57.1	62.7	68.3	64.0	76.8	89.6
13330	114.2	125.4	136.6	124.0	148.8	173.6
14529	57.1	62.7	68.3	64.0	76.8	89.6
14739	57.1	62.7	68.3	64.0	76.8	89.6
21824	68.3	75.0	81.7	75.0	90.0	105.0
22742	57.1	62.7	68.3	64.0	76.8	89.6

	Existing ADT			Build ADT		
ID	2020	2030	2040	2020	2030	2040
23382	57.1	62.7	68.3	64.0	76.8	89.6
23446	57.1	62.7	68.3	64.0	76.8	89.6
24832	57.1	62.7	68.3	63.0	75.6	88.2
25184	57.1	62.7	68.3	63.0	75.6	88.2
Total	**2070.6**	**2273.6**	**2476.6**	**2295.0**	**2754.0**	**3213.0**

3 Estimation of Benefits and Net Benefits

3.1 Analytical Overview

The main benefit categories associated with the project are identified in Table 5 and represent the contribution of the project to USDOT Selection Criterion #2 (Support for Economic Vitality) and other forms of benefits. This section describes the measurement approach used for each benefit or impact category.

Table 5: Benefit Categories

Benefit or Impact Categories	Description
Existing O&M Cost Savings	Reduction in future O&M costs of maintaining bridges in current condition.
Travel Time Savings	Travel time savings for roadway users due to avoided out-of-direction travel; this applies to trucks for load-posted bridges and all vehicles for closed bridges.
Vehicle Operating Cost Savings	Reduction in monetary costs to drivers due to the avoided out-of-direction miles traveled
Crash Risk Reduction	Reduction in property losses, injuries, and deaths due to the improved bridge conditions as well as the reduction in out-of-direction miles traveled
Emissions Reduction	Reduction in air pollutants due to reduction in out-of-direction travel
Pavement Cost reduction	For ODOT and Grant County, the reduction in pavement damage is due to avoided out-of-direction travel; this applies to trucks for load-posted bridges and all vehicles for closed bridges.

The BCA measures benefits against costs throughout a period of analysis beginning at the start of construction and including 30 years of operations. The monetized benefits and costs are estimated in 2018 dollars with future dollars discounted in compliance with USDOT requirements using a 7 percent real rate. The methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices are expressed in 2018 dollars;
- The period of analysis begins in 2019 and ends in 2053. It includes project development and construction in years 2019-2023 and 30 years of operations over the years 2023 through 2053.
- Residual value of the remaining life of bridges is computed and partly accounted for in years 2053 and 2054 for discounting purposes and reflects the original mid-year completion of the project.
- A constant 7 percent real discount rate is assumed throughout the period of analysis;

- Opening year demand is an input to the BCA and is assumed to be fully realized in Year 1 (no ramp-up); and
- Unless specified otherwise, the results shown in this document correspond to the effects of the Full Build alternative, construction and implementation of all 34 bridges.

3.2 Benefit Estimation Methodology and Data

Benefits from the proposed project will alleviate weight restrictions and impending closures that would eliminate the need for vehicles to take a detour to reach their final destination. Fewer vehicle miles traveled reduces travel time, risk for accidents, vehicle operating costs, and air pollution emissions. In addition, because the repaired bridges will be built to current structural standards, Grant County will save maintenance costs, as compared to the average annual costs to maintain bridges in their current conditions. Finally, Grant County saves money on costs that would be incurred to maintain pavement on roadways that are used by vehicles on a detour route. These benefit categories are each discussed in turn:

Bridge Maintenance Cost Savings: Proposed improvements to bridges will lower the annual net cost of maintaining bridges overall. Table 6 lists average costs for maintaining existing bridges of different lengths. Improved bridges would cost considerably less per year. ODOT's best estimate of costs assume that for the first three years, no maintenance is required. Then, over time, annual costs increased from $2,000 to $5,000 by the time it is 20 years old.

Table 6: Assumptions Used to Estimate Bridge Maintenance Cost Savings ($2018)

Parameter	Value	Source
Annual O&M Cost - Existing Bridge < or = 25 ft	$8,817	Grant County
Annual O&M Cost - Existing Bridge >25 ft	$11,043	ODOT
O&M Cost - Improved Bridge < 3 years	$0	ODOT
O&M Cost - Improved Bridge 3 - 10 years	$2,000	ODOT
O&M Cost - Improved Bridge 10 -20 years	$3,500	ODOT
O&M Cost - Improved Bridge >20 years	$5,000	ODOT

Travel Time Savings: Travel time savings accrue because of the ability of drivers to use an improved bridge on a more direct route to their destinations. The value of travel time savings depends on their value of time (VOT) and is adjusted for vehicle occupancy in passenger vehicles. Each bridge with restricted access is assumed to cause a two-mile detour, on average. The travel time for taking the detour is computed from an assumed average speed of 45 miles per hour. In addition, the induced demand of vehicles from bridge repair generates additional benefits. These benefits are computed by applying a 'rule of half' for estimating their consumer surplus.[2]

[2] The rule of half is a standard and reasonable approximation of assessing the value of induced demand. Essentially, it characterizes the average improvement in value to drivers who are only marginally better off to take the new bridge. Computationally, these induced users of the bridge receive only half of the average benefit of baseline users.

Table 7: Assumptions Used to Estimate Travel Time Savings ($2018)

Parameter	Value	Source
Length of bridge detour route (miles)	2	ODOT
Average detour travel speed (mph)	45	Assumption relevant to local roads
Value of Time - passenger vehicles ($/hour)	$14.65	USDOT BCA Guidelines; adjusted to $2018 with a GDP deflator
Value of Time - trucks ($/hour)	$29.51	USDOT BCA Guidelines; adjusted to $2018 with a GDP deflator
Vehicle occupancy (#/vehicle)	1.39	Federal Highway Administration Highway Statistics 2015, Table VM1

Vehicle Operating Cost Savings: These benefits are associated with the decreased distance traveled when a bridge is repaired. Monetary measures are based on average per-mile vehicle operating costs as computed by the Automobile Associate of America (AAA) and by the American Trucking Research Institute (ATRI). The user costs per mile are applied to all miles covered on detour routes by passenger vehicles and trucks, respectively. Each vehicle would use the bridge if it were open, instead of taking a 2 mile detour.

Table 8: Assumptions Used to Estimate Vehicle Operating Cost Savings ($2018)

Parameter	Value	Source
Passenger vehicle costs, ($ / mile)	$0.40	AAA, Your Driving Costs, How much are you really paying to drive?, 2017 Edition; adjusted to $2018 with GDP Deflator
Trucking Costs, ($ / mile)	$0.92	American Transportation Research Institute (ATRI), An Analysis of the Operational Costs of Trucking: 2017 Update, October 2017; adjusted to $2018 with GDP Deflator

Crash Risk Reduction: Reduced miles traveled also decreases the risk of accidents and their associated costs. The crash rates are computed from ten years of accident data in Grant County. The accidents that are located within a 2-mile radius of any bridge are used to estimate the risk of traveling along a detour route for all bridges. An average accident risk is computed for all bridges together under the assumption that the roads are sufficiently similar and that a larger pool of historical accidents generates a more robust average accident rate that is relevant for all bridges. It is assumed that the ODOT estimated ADT volumes linked to the bridges represent only part of users on roadways within the 2-mile radius of a bridge. As such, it is assumed that an equivalent ADT volume uses the roadways around the bridges, but not the bridge itself (because otherwise these vehicles would be captured in the bridge-specific ADT). To determine a total VMT for all vehicles, it is assumed that each vehicle travels 2 miles on the roadway network within the 2-mile radius of each bridge. The monetary benefit of accidents is determined by applying the costs per event by type to the accident rates by type for each avoided mile of travel around each bridge.

Table 9: Assumptions Used to Estimate Crash Risk Reduction Benefits ($2018)

Parameter	Value	Source
Average # of Fatalities / 100,000 VMT	0.010	Computed from ADT within 2 Mi of Bridges
Average # of Class A Injuries / 100,000 VMT	0.017	Computed from ADT within 2 Mi of Bridges
Average # of Class B Injuries / 100,000 VMT	0.047	Computed from ADT within 2 Mi of Bridges
Average # of Class C Injuries / 100,000 VMT	0.024	Computed from ADT within 2 Mi of Bridges
Average # of Property Damage Events / 100,000 VMT	0.115	Computed from ADT within 2 Mi of Bridges
Cost of Fatalities	$9,600,000	USDOT Guidelines
Cost of Injury Class A	$459,100	USDOT Guidelines
Cost of Injury Class B	$125,000	USDOT Guidelines
Cost of Injury Class C	$63,900	USDOT Guidelines
Cost of PDO Events	$3,200	USDOT Guidelines

Pollution Emission Reduction: To estimate the change in air pollution due to vehicle emissions, the Environmental Protection Agency (EPA) MOVES model is used to generate emissions rates at various speeds for automobiles and trucks. Emissions rates are estimated in grams per mile and vary over time, depending on the type of vehicle. The per unit social values for each emission type are then applied to the change in overall emissions following USDOT guidelines to monetize these benefits.

Table 10: Assumptions Used in the Estimation of Environmental Benefits ($2018)

Parameter	Unit	Value	Source
Nitrogen Oxides (NOx)	$ per metric ton	$8,538	US DOT; Corporate Average Fuel Economy for MY2017-MY2025 Passenger Cars and Light Trucks (August 2012), p. 922, Table VIII-16,"Economic Values Used for Benefits Computations (2010 Dollars)"; Updated to 2018 using GDP deflator.
Fine Particulate Matter (PM2.5)		$390,581	
Sulfur Dioxide (SO2)		$50,463	
Volatile Organic Compounds (VOC)		$2,166	

Pavement Cost Reduction: Avoided vehicle miles traveled reduces maintenance costs for Grant County. The reduction in pavement damage is due to avoided out-of-direction travel. This benefit category applies to trucks for load-posted bridges and all vehicles for closed bridges. Estimates of avoided costs per mile by vehicle type are established by USDOT in the BCA guidelines.

Table 11: Assumptions Used to Estimate Pavement Maintenance Cost Savings ($2018)

Parameter	Value	Source
Automobiles ($/mile)	$0.001	USDOT Guidelines (2018); adjusted to $2018 with GDP Deflator
Trucks ($/mile)	$0.15	USDOT Guidelines (2018); adjusted to $2018 with GDP Deflator

4 Results

This section presents the analytical results of estimated costs, benefits and net benefits for both implementation of all projects bundled together and implementation of projects individually. Table 12 presents estimated project benefits. The largest category of discounted benefits is crash risk reduction, estimated at nearly $8.3 million. The next largest categories are vehicle operating cost savings and travel time savings, valued at around $6.9 and $6.5 million, respectively. Lifecycle cost savings of avoided O&M costs for maintaining existing bridges is around $0.8 million. Lifecycle costs savings are relatively small compared to travel time and crash risk because many bridges are anticipated to soon require closure. After closure, all traffic must take a detour route around the bridge and O&M costs are curtailed.

Table 12: Estimated Economic Benefits, by Category (Thousands of $2018)

Benefit Categories	Over Project Lifecycle	
	In Constant Dollars	7% Discount Rate
Existing Bridge O&M Cost Savings	$1,741	$805
Remaining Value of Capital Investment	$7,922	$718
Time Savings	$25,047	$6,513
Crash Risk Reduction	$32,931	$8,294
Pavement Damage Reduction	$926	$268
Vehicle Operating Cost Savings	$24,549	$6,887
Emissions Cost Reduction	$478	$167
Total	**$93,593**	**$23,651**

Net benefits are summarized for projects implemented individually and as a bundle in Table 13. Benefits are the same for both bundled and unbundled implementation since it is assumed that implementation would have a similar schedule in both cases. Savings in total discounted costs for bundling amount to over $1.0 million. If the projects are bundled as one contract, the total net present value amounts to around $14.8 million. The benefit-cost ratio is 2.68 and the projects generate an internal rate of return of 17%.

Table 13: Overall Results of the Benefit-Cost Analysis (Thousands of $2018)

Project Evaluation Metric	Individual Bridges	Bundled Bridges
Total Discounted Benefits (7%)	$23,651	$23,651
Total Discounted Costs (7%)	$9,912	$8,830
Net Present Value (7%)	$13,739	$14,821
Benefit / Cost Ratio (7%)	2.39	2.68
Internal Rate of Return (%)	16%	17%

As shown in Table 14, all projects except one (#23446) are economically worthwhile as individual projects, with the bundled cost savings. The BC Ratios of projects that have positive NPVs range from a high of 5.07 (#4244) to a low of 1.24 (#24832), indicating that all projects are generating

robust returns. Table 15 indicates that all projects have relatively high benefits from time savings, user cost savings and crash risk reduction.

Table 14: Discounted Project Costs and Benefits, by Bridge (Thousands of $2018)

ID	Total NPV	BC Ratio	Total Discounted Costs	Capital Costs	O&M Costs	Total Discounted Benefits + Remaining Capital Value
4244	$857.5	5.07	$232.2	$210.7	$21.5	$1,089.7
4305	$717.0	4.18	$247.0	$225.5	$21.5	$964.0
10177	$479.4	3.12	$247.3	$225.8	$21.5	$726.7
10228	$813.2	4.13	$281.4	$259.9	$21.5	$1,094.6
10799	$481.1	3.15	$245.5	$224.0	$21.5	$726.5
10991	$433.7	2.92	$247.3	$225.8	$21.5	$681.0
11146	$330.9	2.40	$258.7	$237.2	$21.5	$589.6
11151	$334.0	2.45	$252.6	$231.1	$21.5	$586.7
11162	$334.2	2.49	$246.2	$224.7	$21.5	$580.4
11461	$517.9	3.26	$250.8	$229.2	$21.5	$768.7
11471	$521.3	3.31	$247.1	$225.6	$21.5	$768.4
11486	$515.5	3.22	$253.4	$231.9	$21.5	$768.9
11503	$666.4	3.98	$245.3	$223.8	$21.5	$911.7
11514	$332.6	2.47	$247.9	$226.4	$21.5	$580.5
11518	$334.8	2.49	$245.5	$224.0	$21.5	$580.3
11641	$310.9	2.20	$280.8	$259.3	$21.5	$591.7
11818	$494.2	2.93	$276.9	$255.4	$21.5	$771.1
11820	$487.9	2.86	$283.9	$262.4	$21.5	$771.8
11824	$501.5	3.03	$268.9	$247.4	$21.5	$770.4
11841	$320.7	2.29	$269.9	$248.4	$21.5	$590.7
11844	$518.8	3.23	$253.9	$232.4	$21.5	$772.6
11849	$502.0	3.00	$272.4	$250.9	$21.5	$774.4
11863	$507.4	3.07	$266.4	$244.9	$21.5	$773.8
13281	$217.7	1.90	$262.6	$241.1	$21.5	$480.3
13327	$212.6	1.86	$268.2	$246.7	$21.5	$480.8
13330	$602.6	3.43	$269.2	$247.7	$21.5	$871.9
14529	$326.9	2.44	$249.0	$227.5	$21.5	$575.9
14739	$126.9	1.51	$268.5	$247.0	$21.5	$395.5
21824	$647.3	3.64	$266.4	$244.9	$21.5	$913.7
22742	$323.9	2.32	$266.4	$244.9	$21.5	$590.3
23382	$523.2	3.30	$249.0	$227.5	$21.5	$772.2
23446	-$34.5	0.87	$284.3	$262.8	$21.5	$249.7
24832	$57.5	1.24	$259.1	$237.6	$21.5	$316.6
25184	$504.7	3.07	$265.4	$243.9	$21.5	$770.1
Total	**$14,821.5**	**2.83**	**$8,829.7**	**$8,098.6**	**$731.0**	**$23,651.2**

Table 15: Sources of Benefits, by Bridge (Thousands of $2018)

ID	Total Benefits	Remaining Value of Capital Investment	Time Savings	Crash Risk Reduction	Pavement Damage Reduction	Fuel Cost Savings	Emissions Cost	Existing O&M Cost Savings
4244	$1,089.7	$18.6	$318.2	$399.8	$12.1	$333.5	$7.7	$0.0
4305	$964.0	$19.9	$224.0	$475.7	$7.3	$232.2	$4.9	$0.0
10177	$726.7	$20.0	$209.1	$259.6	$7.3	$218.0	$4.8	$7.9
10228	$1,094.6	$23.1	$318.2	$400.1	$12.1	$333.5	$7.7	$0.0
10799	$726.5	$19.8	$209.1	$259.6	$7.3	$218.0	$4.8	$7.9
10991	$681.0	$20.0	$192.8	$242.6	$7.3	$200.8	$4.2	$13.4
11146	$589.6	$21.0	$155.9	$193.4	$7.3	$167.4	$4.4	$40.1
11151	$586.7	$20.5	$154.7	$193.4	$7.3	$166.3	$4.4	$40.1
11162	$580.4	$19.9	$155.9	$193.4	$7.3	$167.4	$4.4	$32.0
11461	$768.7	$20.3	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
11471	$768.4	$19.9	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
11486	$768.9	$20.5	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
11503	$911.7	$19.7	$266.8	$335.0	$8.6	$275.9	$5.7	$0.0
11514	$580.5	$20.0	$155.9	$193.4	$7.3	$167.4	$4.4	$32.0
11518	$580.3	$19.8	$155.9	$193.4	$7.3	$167.4	$4.4	$32.0
11641	$591.7	$23.1	$155.9	$193.4	$7.3	$167.4	$4.4	$40.1
11818	$771.1	$22.7	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
11820	$771.8	$23.4	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
11824	$770.4	$22.0	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
11841	$590.7	$22.1	$155.9	$193.4	$7.3	$167.4	$4.4	$40.1
11844	$772.6	$20.6	$225.9	$280.0	$7.3	$234.0	$4.9	$0.0
11849	$774.4	$22.3	$225.9	$280.0	$7.3	$234.0	$4.9	$0.0
11863	$773.8	$21.7	$225.9	$280.0	$7.3	$234.0	$4.9	$0.0
13281	$480.3	$21.4	$115.4	$141.5	$7.3	$128.9	$4.2	$61.6
13327	$480.8	$21.9	$115.4	$141.5	$7.3	$128.9	$4.2	$61.6
13330	$871.9	$22.0	$227.5	$283.1	$14.6	$254.6	$8.4	$61.6
14529	$575.9	$20.1	$156.6	$197.9	$7.3	$163.0	$3.1	$27.8
14739	$395.5	$21.9	$84.6	$101.0	$7.3	$99.6	$4.1	$76.9
21824	$913.7	$21.7	$266.8	$335.0	$8.6	$275.9	$5.7	$0.0
22742	$590.3	$21.7	$155.9	$193.4	$7.3	$167.4	$4.4	$40.1
23382	$772.2	$20.1	$225.9	$280.0	$7.3	$234.0	$4.9	$0.0
23446	$249.7	$23.4	$33.8	$30.0	$7.3	$51.3	$4.0	$99.9
24832	$316.6	$21.0	$57.2	$63.8	$7.3	$73.5	$4.0	$89.7
25184	$770.1	$21.6	$224.0	$280.0	$7.3	$232.2	$4.9	$0.0
Total	**$23,651.2**	**$717.7**	**$6,513.3**	**$8,293.6**	**$268.2**	**$6,886.7**	**$166.8**	**$804.9**

5 BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on a large number of assumptions and long-term projections, both of which are subject to considerable uncertainty.

The primary purpose of the sensitivity analysis is to help identify the variables and model parameters whose variations have the greatest impact on the BCA outcomes: the "critical variables."

The sensitivity analysis can also be used to:

- Evaluate the impact of changes in individual critical variables – how much the final results would vary with reasonable departures from the "preferred" or most likely value for the variable; and
- Assess the robustness of the BCA and evaluate, in particular, whether the conclusions reached under the "preferred" set of input values are significantly altered by reasonable departures from those values.

The outcomes of the quantitative analysis for the project using a 7 percent discount rate are summarized in the table below. The table provides the percentage changes in project NPV associated with variations in variables or parameters (listed in row), as indicated in the column headers. For example, a 25 percent reduction in the value of time leads to an 11 percent reduction in the project NPV. A 20 percent reduction in ADT alone would lead to an 18 percent reduction in NPV.

These results justify the overall conclusion that the projects are economically worthwhile. From the results alone, only a highly unlikely combination of poorly estimated cost and benefit (e.g. ADT, costs, value of time, etc.) could cause the costs to exceed benefits. As such, this sensitivity analysis provides substantial confidence in the success of these projects in generating positive net value.

Table 16: Assessment of BCA Sensitivity, Summary

Parameters	Change in Parameter Value	Bundled Bridges		
		New NPV	% Change in NPV	New B/C Ratio
Value of Travel Time	-25%	$13,193	-11%	2.49
	25%	$16,450	11%	2.86
Value of Statistical Life	$5.4 million	$11,696	-21%	2.32
	$13.6 million	$17,798	20%	3.02
Change in VMT	20% Reduction	$12,091	-18%	2.37
Analysis Period	20 Years	$11,354	-23%	2.32
Capital Cost Estimate - Change in Bundling Savings	25% Reduction	$15,951	8%	3.10
	25% Increase	$13,692	-8%	2.36