Benefit-Cost Analysis

Executive Summary

This memorandum summarizes the approach used for conducting the benefit-cost analysis (BCA) for the Highway 265 Widening and Relocation project in Springdale and Bethel Heights, Arkansas. A project matrix, shown in Table 1, summarizes the components of this project. The project matrix describes the baseline conditions, proposed improvements, types of anticipated impacts, and economic benefits.

Table 1. Project Matrix

Current Baseline	Proposed Improvements	Type of Impacts	Economic Benefit
A high volume, 1.93 mile section of principal arterial that parallels I-49 and U.S. 71 and consists of two travel lanes with no shoulders. The facility suffers from a lack of capacity, poor pavement condition, and narrow right of way.	Widening, some realignment, curb and gutter, bike lanes, and sidewalks.	Improved connectivity; Accommodate alternative modes; Increased capacity; Reduced delay; Improved safety; Enhanced mobility	Monetized value of reduced travel times, operating costs, and crash reduction savings

Project Benefits

Based on travel time savings, reduction in operating costs, crash reduction savings, and the project cost, the project benefit cost ratio ranges from 0.54 to 1.18, depending on the discount rate applied (See Table 2).

Table 2. Summary of Benefit-Cost Analysis

Benefit/Cost Category	No Discount	Discounted at 3%	Discounted at 7%
Vehicle Operating Cost Savings	$809,033	$527,031	$316,446
Travel Time Cost Savings	$8,728,867	$5,686,276	$3,414,215
Total Crash Reduction Cost Savings	$22,480,825	$14,644,761	$8,793,164
Sum of Benefits	**$32,018,725**	**$20,858,068**	**$12,523,825**
Project Life Cycle Costs	**$27,120,000**	**$25,305,596**	**$23,184,011**
B/C Ratio	**1.18**	**0.82**	**0.54**

Baseline Conditions

The existing 1.98-mile segment of Highway 265 from Randall Wobbe Lane – Highway 264 is a two-lane roadway paralleling the major north-south facilities in the region (I-49 and Highway 71). The current facility is known locally as Old Wire Road. Over half of the length of the project has a surface classified as poor. Analysis of pavement roughness data shows that the average pavement international roughness index (IRI) for the project corridor is 149. Comparison of the collected IRI values with the FHWA recommendations shows that 1.3 miles (61%) of the 1.98-mile project do not meet the good pavement criteria (IRI below 95). A combination of poor roadway condition, narrow right of way, and curb cuts with minimal turning radii results in delays, excessive emissions, and high operating costs for the users. The estimated costs to users under the baseline conditions (assuming that current conditions will continue) for the next 20 years is categorized in two parts:

- User operating costs due to poor roadway conditions
- Travel time delay costs due to reduced free-flow speed

User operating costs due to poor roadway conditions

In order to estimate the user operating cost due to poor roadway conditions we estimate the impacts of roadway IRI on fuel, tire, and maintenance and repair costs. A study by Chatti and Zaabar (2012) on the effects of pavement condition on vehicle operating costs conducted under the National Cooperative highway Research program (NCHRP) Report 720[1], shows that an average reduction of 63.4 inch/mile in IRI results in a reduction in vehicle operating costs. The impact of roughness on operating expenses can be monetized using average speeds and vehicle class distribution along the roadway as shown on Figure 1: Effect of Roughness on Vehicle Operating Costs[2].

The current roadway IRI of Highway 265 averages 149 inch/mile, which equates to a value between IRI classes 2 and 3 above, and the speeds are between 35 and 55 mph, a series of interpolation calculations were performed to determine a difference of $0.00445/mile for the vehicle operating costs from 40 to 45 mph.

We estimate the annual increase in operating costs due to poor roadway conditions using the annual average daily traffic (AADT) of the study corridor. The higher the IRI of the surface, the higher the overall operating costs. The estimates assume that traffic projections will grow by a factor of 1.0148 annually from 2020 to 2040 (an average annual rate of 1.0148). Therefore, the annual additional vehicle operating costs equal:

[(AADT) * (1.98 miles) * $1.0045 * (365 days)]

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[1] Chatti, K., & Zaabar, I. (2012). "Estimating the effects of pavement condition on vehicle operating costs" (NCHRP 720). Transportation Research Board.

[2] Chatti, K., & Zaabar, I. (2012). "Estimating the effects of pavement condition on vehicle operating costs" (NCHRP 720). Transportation Research Board.

Figure 1: Effect of Roughness on Vehicle Operating Costs

Speed	Vehicle Class	Vehicle Operating Costs						
		Baseline Conditions (¢/km)	Baseline Conditions (¢/mi)	Adjustment Factors from the Baseline Conditions				
		IRI (m/km)						
		1		2	3	4	5	6
56 km/h (35 mph)	Medium car	8.8	14.0	1.02	1.04	1.08	1.15	1.22
	Van	10.0	16.1	1.01	1.02	1.05	1.11	1.18
	SUV	10.2	16.3	1.02	1.03	1.09	1.20	1.34
	Light truck	14.9	23.9	1.01	1.02	1.06	1.13	1.22
	Articulated truck	36.1	57.7	1.02	1.03	1.07	1.13	1.19
88 km/h (55 mph)	Medium car	10.5	16.8	1.02	1.04	1.08	1.15	1.22
	Van	12.6	20.2	1.01	1.01	1.05	1.11	1.17
	SUV	13.0	20.8	1.02	1.03	1.09	1.20	1.32
	Light truck	21.6	34.6	1.01	1.02	1.05	1.12	1.20
	Articulated truck	56.7	90.7	1.01	1.02	1.05	1.10	1.15
112 km/h (70 mph)	Medium car	13.3	21.3	1.02	1.03	1.07	1.14	1.21
	Van	16.5	26.5	1.01	1.01	1.04	1.10	1.16
	SUV	17.6	28.2	1.01	1.03	1.08	1.18	1.29
	Light truck	30.1	48.1	1.01	1.01	1.04	1.10	1.17
	Articulated truck	81.2	130.0	1.01	1.02	1.04	1.08	1.13

1 m/km = 63.4 (in./mi)

The net present value (NPV) of annual operating costs is then calculated using the 3% and 7% discount rates as recommended by USDOT TIGER grant guidelines[3]. Table 3 summarizes the operating cost analysis over the next 20 years. The NPV of operating costs to users, assuming that current conditions exist for the next 20 years, is estimated to be $71,309,448.

Travel time delay costs due to reduced free-flow speed

Similar to user operating costs, we estimate travel delay costs that result from reduced free-flow speed along the Highway 265 corridor. The current speed limit on the existing Highway 265 facility is 40 mph. Along the proposed route, the speed limit will be 45 mph. The travel corridor for the Highway 265 Widening and Relocation project is 1.98 miles. With the higher travel speed, the travel times will decrease from 0.0375 hours (2.25 minutes) to 0.0354 hours (2.13 minutes) in 2040 under the build scenario. This is a difference of 0.0021 hours per vehicle.

3 US Department of Transportation (USDOT) (2015). "Benefit-Cost Analyses Guidance for TIGER Grant Applicants." Available at: http://www.dot.gov/tiger/guidance#sthash.0MI9ixrq.dpuf

Table 1. Baseline User Operating Costs due to Rough Roadway Conditions

Year	Calendar Year	VMT	Annual Operating Cost	NPV of Veh. Operating Costs (3%) [Annual Operating Cost/(1+3%)^Year]	NPV of Veh. Operating Costs (7%) [Annual Operating Cost /(1+7%)^Year]
0	2020	23,364	$0	$0	$0
1	2021	23,770	$7,843,218	$6,765,628	$5,592,106
2	2022	24,176	$7,977,150	$6,680,738	$5,315,512
3	2023	24,582	$8,111,083	$6,595,052	$5,051,175
4	2024	24,988	$8,245,015	$6,508,691	$4,798,674
5	2025	25,394	$8,378,947	$6,421,766	$4,557,592
6	2026	25,799	$8,512,880	$6,334,382	$4,327,517
7	2027	26,205	$8,646,812	$6,246,641	$4,108,038
8	2028	26,611	$8,780,745	$6,158,638	$3,898,756
9	2029	27,017	$8,914,677	$6,070,462	$3,699,274
10	2030	27,423	$9,048,610	$5,982,197	$3,509,207
11	2031	27,829	$9,182,542	$5,893,925	$3,328,176
12	2032	28,235	$9,316,475	$5,805,719	$3,155,812
13	2033	28,641	$9,450,407	$5,717,652	$2,991,757
14	2034	29,047	$9,584,340	$5,629,790	$2,835,660
15	2035	29,453	$9,718,272	$5,542,195	$2,687,183
16	2036	29,858	$9,852,205	$5,454,927	$2,545,997
17	2037	30,264	$9,986,137	$5,368,041	$2,411,783
18	2038	30,670	$10,120,070	$5,281,589	$2,284,233
19	2039	31,076	$10,254,002	$5,195,618	$2,163,050
20	2040	31,482	$10,387,935	$5,110,176	$2,047,946
Total Cost to Users			$182,311,524	$118,763,826	$71,309,448

The estimates assume that traffic projections will grow at the rate of 1.0148 annually from 2020 to 2040. The recommended average hourly value of time by USDOT is $16.5 per hour for automobiles and $28.12 per hour for trucks in 2013 dollars. Based on a truck percentage of 7% within the corridor, the average value of time is $17.30/hour (2013$). The annual travel time delay costs equal:

[(AADT) * ($17.3/hr) * (delay= 0.0021 hour) * (365 days)]

Table 4 describes the summary of travel time delay impacts analysis.

Table 2. Travel Time Delay Impacts

Year	Calendar Year	Travel Time Reduction (hours)	Annual Travel Time Delays (365 days) [Delay hrs*365] (hours)	Total Value of Travel Time Delays ($2013)[Annual Delay* $17.3 per hour]	NPV of Travel Time Delays (3%)	NPV of Travel Time Delays (7%)
0	2020	0	-	$0	$0	$0
1	2021	59	21,690	$375,524	$323,931	$267,744
2	2022	60	22,060	$381,937	$319,866	$254,501
3	2023	61	22,431	$388,349	$315,764	$241,844
4	2024	62	22,801	$394,762	$311,629	$229,755
5	2025	63	23,172	$401,174	$307,467	$218,212
6	2026	64	23,542	$407,587	$303,283	$207,197
7	2027	66	23,912	$413,999	$299,082	$196,688
8	2028	67	24,283	$420,412	$294,869	$186,668
9	2029	68	24,653	$426,825	$290,647	$177,117
10	2030	69	25,023	$433,237	$286,421	$168,017
11	2031	70	25,394	$439,650	$282,194	$159,349
12	2032	71	25,764	$446,062	$277,971	$151,097
13	2033	72	26,135	$452,475	$273,755	$143,242
14	2034	73	26,505	$458,887	$269,548	$135,768
15	2035	74	26,875	$465,300	$265,354	$128,659
16	2036	75	27,246	$471,712	$261,176	$121,899
17	2037	76	27,616	$478,125	$257,016	$115,473
18	2038	77	27,987	$484,537	$252,876	$109,366
19	2039	78	28,357	$490,950	$248,760	$103,564
20	2040	79	28,727	$497,362	$244,669	$98,053
Total Travel Time Delay Costs				$8,728,867	$5,686,276	$3,414,215

The net present value (NPV) of annual travel delay costs are then calculated using the 3% and 7% discount rates as recommended by USDOT TIGER grant guidelines. The NPV of travel delay costs to users, assuming that current conditions exist for the next 20 years, is estimated to be $3,414,215.

The overall impact for users due to inaction in the next 20 years is the sum of increased operating costs ($71,309,448) and travel time delays ($3,414,215). The total NPV of both these impacts are $74,723,663.

Proposed Alternative Benefit- Cost Analysis

In this section we describe the method used for estimating the benefits and life cycle costs following the implementation of the Highway 265 Widening and Relocation project. In calculation of project benefits we use the guidelines provided by USDOT for TIGER grant applications and follow the same methodology in the previous section.

Project Benefits

We evaluate the benefits of the Highway 265 Widening and Relocation project reconstruction and road diet improvements in the following areas:

- Vehicle Operating Cost Savings
- Travel Time Cost Savings
- Crash Reduction Savings

Vehicle Operating Cost Savings

As described in the previous section, the poor roadway conditions and high values of IRI have direct impact on user operating costs. The impacts of high IRI on vehicle operating costs are summarized in Table 5. The benefits of the reconstruction of the pavement can be characterized by reducing the user operating costs due to improved pavement performance.

We estimate the annual increase in operating costs due to poor roadway conditions using the annual average daily traffic (AADT) of the study corridor. The higher the IRI of the surface, the higher the overall operating costs. The estimates assume that traffic projections will grow by a factor of 1.0148 annually from 2020 to 2040 (an average annual rate of 1.0148). Therefore, the annual additional vehicle operating costs equal:

[(AADT) * (1.98 miles) * $0.0045 * (365 days)]

The net present value (NPV) of annual operating costs is then calculated using the 3% and 7% discount rates as recommended by USDOT TIGER grant guidelines[4]. Table 5 summarizes the operating cost analysis over the next 20 years. The NPV (at 7%) of operating costs to users, assuming that current conditions exist for the next 20 years, is estimated to be $316,446.

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[4] US Department of Transportation (USDOT) (2015). "Benefit-Cost Analyses Guidance for TIGER Grant Applicants." Available at: http://www.dot.gov/tiger/guidance#sthash.0MI9ixrq.dpuf

Table 3. User Operating Cost Savings Due to Improved Roadway Conditions

Year	Calendar Year	AADT	Vehicle Operating Costs [AADT*Avg Veh OpEx/mile*1.98 miles* (6.5% Poor Roadway Effects)*365 days]	NPV of Veh. Operating Costs (3%) [Vehicle Operating Costs/(1+3%)^Year]	NPV of Veh. Operating Costs (7%) [Vehicle Operating Costs /(1+7%)^Year]
0	2020	23,364	$0	$0	$0
1	2021	23,770	$34,805	$30,023	$24,816
2	2022	24,176	$35,400	$29,647	$23,588
3	2023	24,582	$35,994	$29,266	$22,415
4	2024	24,988	$36,588	$28,883	$21,295
5	2025	25,394	$37,183	$28,497	$20,225
6	2026	25,799	$37,777	$28,110	$19,204
7	2027	26,205	$38,371	$27,720	$18,230
8	2028	26,611	$38,966	$27,330	$17,301
9	2029	27,017	$39,560	$26,939	$16,416
10	2030	27,423	$40,154	$26,547	$15,573
11	2031	27,829	$40,749	$26,155	$14,769
12	2032	28,235	$41,343	$25,764	$14,004
13	2033	28,641	$41,937	$25,373	$13,276
14	2034	29,047	$42,532	$24,983	$12,584
15	2035	29,453	$43,126	$24,594	$11,925
16	2036	29,858	$43,721	$24,207	$11,298
17	2037	30,264	$44,315	$23,821	$10,703
18	2038	30,670	$44,909	$23,438	$10,137
19	2039	31,076	$45,504	$23,056	$9,599
20	2040	31,482	$46,098	$22,677	$9,088
Total Operating Cost Savings			$809,033	$527,031	$316,446

Travel Time Cost Savings

Similar to travel time delay cost estimation, the value gained from an increase in free-flow speed represents itself in terms of faster travel. The project corridor has a length of 1.98 miles and as a result, travel times will decrease by 0.0021 hours per vehicle. The estimates assume that traffic projections will grow at the rate of 1.0148 annually from 2020 to 2040. The recommended average hourly value of time by USDOT is $17.30 per hour for 2013. Therefore, the annual travel time savings equal:

[(AADT) * ($17.30/hr) * (time savings= 0.0021 hour) * (365 days)]

The NPV of annual travel time savings costs are then calculated using the 3% and 7% discount rates as recommended by USDOT TIGER grant guidelines. The NPV of travel time savings costs to users in the next 20 years, assuming that project is implemented, is estimated to be $3,414,215. Table 6 summarizes these travel time savings benefits.

Table 4. Travel Time Savings Benefits

Year	Calendar Year	Travel Time Reduction (hours)	Annual Travel Time Delays (365 days) [Delay hrs*365] (hours)	Total Value of Travel Time Delays ($2013)[Annual Delay* $17.3 per hour]	NPV of Travel Time Delays (3%)	NPV of Travel Time Delays (7%)
0	2020	0	-	$0	$0	$0
1	2021	59	21,690	$375,524	$323,931	$267,744
2	2022	60	22,060	$381,937	$319,866	$254,501
3	2023	61	22,431	$388,349	$315,764	$241,844
4	2024	62	22,801	$394,762	$311,629	$229,755
5	2025	63	23,172	$401,174	$307,467	$218,212
6	2026	64	23,542	$407,587	$303,283	$207,197
7	2027	66	23,912	$413,999	$299,082	$196,688
8	2028	67	24,283	$420,412	$294,869	$186,668
9	2029	68	24,653	$426,825	$290,647	$177,117
10	2030	69	25,023	$433,237	$286,421	$168,017
11	2031	70	25,394	$439,650	$282,194	$159,349
12	2032	71	25,764	$446,062	$277,971	$151,097
13	2033	72	26,135	$452,475	$273,755	$143,242
14	2034	73	26,505	$458,887	$269,548	$135,768
15	2035	74	26,875	$465,300	$265,354	$128,659
16	2036	75	27,246	$471,712	$261,176	$121,899
17	2037	76	27,616	$478,125	$257,016	$115,473
18	2038	77	27,987	$484,537	$252,876	$109,366
19	2039	78	28,357	$490,950	$248,760	$103,564
20	2040	79	28,727	$497,362	$244,669	$98,053
Total Travel Time Delay Costs				$8,728,867	$5,686,276	$3,414,215

Safety and Crash Reduction Benefits

A comparison of the fatal and non-fatal crash rates for 2013 are displayed in Table 7 with the accompanying crash cost (per VMT):

Table 7. 2013 Crash Rates and Costs for Build and No-Build

Type of Crash	Crash Rate (Build) (per MVM)	Crash Cost (per VMT)	Crash Rate (No-Build) (per MVM)	Crash Cost (per VMT)
Fatal Crash Rate	0.0083	$0.078	0.0139	$0.131
Non-Fatal Crash Rate	2.24	$0.290	2.79	$0.361
TOTAL COST		**$0.368**		**$0.492**

These costs were determined by using the Tiger Benefit Cost Analysis (BCA) Resource Guide. The various severities of crashes have an associated cost to society. When the distribution of crashes (by percentage) is applied to the costs per crash type, a total crash cost per mile is determined. This results in a non-fatal average crash cost of $129,490. The corresponding cost associated with fatal crashes is $9.4 million. This is then equated to a safety cost per mile for the existing or no-build facility and for the improved facility. The same VMT figures are used for the safety comparison as have been used in the other tables.

To quantify the benefits of the Highway 265 Widening and Relocation Project we calculate the safety cost per mile of both the build and no-build scenarios to determine the daily benefits. Using the crash costs for 2013 we identify crash costs for the next 20 years based on AADT growth. The NPV of reduction in crash costs is then calculated by discounting at 3% and 7% rates as recommended by USDOT TIGER Grant recommendations. Table 8 presents the summary of crash reduction benefits.

Project Life Cycle Cost Analysis

Planning estimates the project construction costs total $16,800,000. The preliminary engineering (PE) is estimated at $840,000. Construction engineering is estimated at 10% of the Construction Cost, $1,680,000. Right of Way and Utilities are estimated at $7,800,000. The project schedule mandates the project start year as 2018, and schedules the finish year as 2020. The distribution of both the Construction and Construction Engineering payments are based on one third for each of the three years of construction.

The project operations and maintenance costs are not included in this estimate. It is the long-standing tradition that when a state highway is relocated, or constructed on new location, the ownership of the original roadway is transferred to the local project partner, thereby not increasing the operations and maintenance costs for the corridor. Table 9 summarizes the project cost estimate.

Table 8. Safety Benefits

	Build VMT (ALL)	No-Build VMT (ALL)	Safety Benefit (Non-Disc.)	Safety Benefit Disc. (3%)	Safety Benefit Disc. (7%)
2021	23,770	23,770	$967,147	$834,269	$689,562
2022	24,176	24,176	$983,662	$823,801	$655,456
2023	24,582	24,582	$1,000,177	$813,236	$622,860
2024	24,988	24,988	$1,016,692	$802,586	$591,724
2025	25,394	25,394	$1,033,208	$791,868	$561,996
2026	25,799	25,799	$1,049,723	$781,092	$533,626
2027	26,205	26,205	$1,066,238	$770,273	$506,562
2028	26,611	26,611	$1,082,753	$759,421	$480,755
2029	27,017	27,017	$1,099,268	$748,548	$456,157
2030	27,423	27,423	$1,115,784	$737,664	$432,720
2031	27,829	27,829	$1,132,299	$726,780	$410,397
2032	28,235	28,235	$1,148,814	$715,903	$389,143
2033	28,641	28,641	$1,165,329	$705,043	$368,913
2034	29,047	29,047	$1,181,844	$694,209	$349,665
2035	29,453	29,453	$1,198,360	$683,408	$331,356
2036	29,858	29,858	$1,214,875	$672,647	$313,947
2037	30,264	30,264	$1,231,390	$661,933	$297,397
2038	30,670	30,670	$1,247,905	$651,272	$281,669
2039	31,076	31,076	$1,264,421	$640,671	$266,726
2040	31,482	31,482	$1,280,936	$630,135	$252,532
Total Economic Benefits of Safety Improvements			$22,480,825	$14,644,761	$8,793,164

Table 9. Project Cost Estimate[5]

Work Item	Amount	Year of Expenditure
Construction	$16,800,000	2018-2020
Construction Engineering	$1,680,000	2018-2020
Preliminary Engineering	$840,000	2017
Right of Way	$3,400,000	2017
Utilities	$4,400,000	2017
Operations and Maintenance	$0	2020-2040
Total	$27,120,000	

[5] Greening the Gateways. (2015). "Opinion of Probable Cost for North State Street Segment of Independent Utility." Available at: http://www.greeningthegateways.com/appendix-c-cost-estimates.html

Table 10 presents the life cycle cost analysis of the proposed Highway 265 Widening and Relocation project.

Table 10. Project Life Cycle Cost Analysis

Year	Calendar Year	Initial Capital Cost	NPV of Annual Costs (3%)	NPV of Annual Costs (7%)
0	**2016**	$0	$0	$0
1	**2017**	$8,640,000	$8,388,350	$8,074,766
2	**2018**	$6,172,320	$5,818,004	$5,391,143
3	**2019**	$6,153,840	$5,631,635	$5,023,367
4	**2020**	$6,153,840	$5,467,607	$4,694,735
5	**2021**	$0	$0	$0
6	**2022**	$0	$0	$0
7	**2023**	$0	$0	$0
8	**2024**	$0	$0	$0
9	**2025**	$0	$0	$0
10	**2026**	$0	$0	$0
11	**2027**	$0	$0	$0
12	**2028**	$0	$0	$0
13	**2029**	$0	$0	$0
14	**2030**	$0	$0	$0
15	**2031**	$0	$0	$0
16	**2032**	$0	$0	$0
17	**2033**	$0	$0	$0
18	**2034**	$0	$0	$0
19	**2035**	$0	$0	$0
20	**2036**	$0	$0	$0
Total Project Costs		**$27,123,000**	**$25,305,596**	**$23,184,011**

Summary and Conclusions

This memorandum describes the methodology used for conducting the benefit-costs analysis for the Highway 265 Widening and Relocation project. The economic benefits of implementing the project include cost savings for users due to reduced vehicle operating costs and reduced travel delays. The summary of benefits-cost analysis yields a B/C ratio of 0.54 for the 1.98-mile roadway project. Table 11 summaries the benefit-cost analysis.

Table 11. Summary of Benefit-Cost Analysis

Benefit/Cost Category	No Discount	Discounted at 3%	Discounted at 7%
Vehicle Operating Cost Savings	$809,033	$527,031	$316,446
Travel Time Cost Savings	$8,728,867	$5,686,276	$3,414,215
Total Crash Reduction Cost Savings	$22,480,825	$14,644,761	$8,793,164
Sum of Benefits	**$32,018,725**	**$20,858,068**	**$12,523,825**
Project Life Cycle Costs	**$27,120,000**	**$25,305,596**	**$23,184,011**
B/C Ratio	**1.18**	**0.82**	**0.54**