Appendix 8

Benefit-Cost Analysis

1. INTRODUCTION

Benefit-Cost Analysis (BCA) is a systematic approach used to compare the benefits and costs of alternatives to determine sound investment decisions. BCA was performed using a Nevada-specific corridor version of the California Life-Cycle Benefit-Cost Analysis Model (Cal-B/C Corridor 6.2). The BCA followed the Cal-B/C Corridor methodology and tools used by Southern Nevada Traffic Study (SNTS). Cal-B/C Corridor estimates benefits using changes in VMT and VHT from micro-simulation models. The project capital costs were estimated using NDOT Wizard. The benefit-cost ratios of the two Build options were analyzed and compared with the No-Action.

2. PROJECT COSTS

2.1. Capital Costs

Table 1 summarizes the estimated capital costs for the Build Options 1 and 2 (Refer to Cost Assessment Report for detail project costs). For the purpose of BCA, it is assumed that all the project capital costs are incurred during year 2020 and the opening year of the project is year 2021. In the BCA, the costs are discounted to 2018 dollars based on year of expenditure.

Table 1: Estimated Capital Costs (2019$)

Item	Option 1	Option 2
Capital Costs (in mil $)	$261.6	$237.8

2.2. Operations and Maintenance Costs

Operations and Maintenance (O&M) costs are based on the net increase between maintaining the existing facility and maintaining the larger proposed facility. Unit costs for pavement maintenance were provided by NDOT and assume a mill and overlay for asphalt pavement on an eight-year cycle, and spall repairs and limited slab replacement for concrete pavement on a ten-year cycle. Unit costs for bridge maintenance were estimated assuming a two-year inspection cycle and deck repair costs similar to pavement maintenance. All costs were converted to a cost per square-yard per year and shown in Table 2.

Table 2: Operations and Maintenance Costs of Additional Infrastructure

Description	Added Material (sq yd)	Cost/sq yd/year (2019$)	Annual Maintenance Cost
Build Option 1			
Roadways: Asphalt Pavement	368,756	1.50	$552,706
Concrete Bridges	1,667	2.46	$4,105
Steel Bridges	68,933	3.21	$221,399
		Total	**$778,210**
Build Option 2			
Roadways: Asphalt Pavement	223,493	1.50	$334,980
Concrete Bridges	1,667	2.46	$4,105
Steel Bridges	41,541	3.21	$133,421
		Total	**$472,506**

3. QUANTITATIVE BENEFITS

3.1. Travel Demand and Operations Modeling

As part of the quantitative analysis, travel demand forecast and traffic operations performed using Aimsun Next traffic model were utilized. Traffic analysis was performed for the 2017 existing condition, 2040 No-Action and Build options. The evaluation output provides VMT and VHT for the No-Action and Build options. The VMT and VHT values for the year 2020 were estimated using Average Annual Daily Traffic growth rates from Travel Demand Model. The values of VMT and VHT between 2020 and 2040 were estimated using a straight-line interpolation over the 20-year period which is the end of the 20-year BCA horizon. Average daily estimates of VMT and VHT were annualized for all years from 2021 and 2040. The detailed methodology including the equations are provided in the *Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, October 2018*.

3.2. Travel Time Savings

The travel time savings was calculated as the difference in the VHT plus the difference in latent delay between No-Action and Build options. Latent delay is the delay of vehicles waiting to enter the models due to congestion/bottleneck in the traffic operations. Cal-B/C Corridor model multiplies the number of hours saved by personal vehicle drivers and trucks drivers by their corresponding vehicle occupancy rates and value of time. The average vehicle occupancy is 1.33 for autos and 1.00 for trucks in both AM and PM conditions, from the RTC travel demand origin-destination (OD) matrices. Overall, it is estimated that 4.6% of trucks in AM and 7.6% in PM and the remainder by local vehicular traffic. The truck percentage was estimated using the truck OD matrices. The value of time parameters (Table 3) was calculated in accordance with USDOT Guidance and the details are provided in *Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, October 2018*.

Table 3: Vehicle Operating Costs per-mile, Cars and Trucks (2018$)

Item	Auto	Truck
Travel Time Cost ($/hour)	$ 11.00	$ 37.20

Source: Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, Oct 2018; Pg F-6; Table 2

For the project, the net present value (NPV) of travel time savings over the 20-year analysis period is $867.6 million for Build Option 1 and $847.3 million for Build Option 2.

3.3. Crash Cost Savings

Crash data, crash costs parameters, and crash cost savings methodology is utilized from SNTS study Safety Analysis. Cal-B/C Corridor by default does not include crash cost calculations in the BCA. Crash cost savings of the No-Action and Build Options were estimated based on the forecasted reduction in the number of crashes in the project area attributable to the improvements. Crash cost savings for the analyzed options stem from a reduction in accident rates; reduction in the frequency or severity of accidents for a given level of traffic, because the improvements make the facility safer and make the traffic less prone to accidents.

Accident reductions were estimated using the crash rates by severity, crash reduction factors, and VMT in the No-Action compared to the Build Options. Crash rates were estimated using the crash data provided by NDOT, and utilized in the No-Action crash forecasts. For the Build Options, crash reduction/modification factors were used to estimate reduction in crashes. Crash reduction benefits were quantified using the number of crashes avoided as a result of the project improvements. The difference between monetized accident costs under the No-Action and Build Options (i.e., improved facility) is the analyzed benefit (reduction in crash costs).

Table 4 provides a summary of the differences in accidents between the No-Action and Build Options for 2020 and 2040, and for accident severity types: fatal (K), severe (A), moderate (B), minor (C), and property damage only (PDO). Linear interpolation techniques were used to derive estimates of accident reduction in all years between the opening year (2021) and the horizon year (2040).

Table 4: Vehicle Operating Costs per-mile, Cars and Trucks (2018$)

Corridor	Year	Crash reduction (in absolute values)				
		K	A	B	C	PDO
No-Action vs Build Option 1						
I-515	2020	-0.02	-0.10	-0.48	-2.27	-0.37
I-515	2040	0.02	-0.01	-0.01	0.57	4.33
I-215	2020	0.21	0.42	2.19	23.31	33.89
I-215	2040	0.31	0.64	3.19	35.19	50.00
System-to-System	2020	0.01	0.02	0.22	0.59	1.45
System-to-System	2040	0.01	0.02	0.87	2.57	6.38
No-Action vs Build Option 2						
I-515	2020	0.03	0.08	0.45	2.96	6.58
I-515	2020	0.01	-0.02	0.00	0.61	4.63
I-215	2020	0.21	0.42	2.19	23.31	33.89
I-215	2040	0.31	0.64	3.19	35.19	50.00
System-to-System	2040	0.01	0.01	0.21	0.58	1.28
System-to-System	2040	0.01	0.02	0.43	2.27	2.84

Crash cost savings for each year were estimated by multiplying the number of avoided crashes by severity type by their associated costs. Crash costs per event was converted to costs per crash to correspond with the data on crash reduction. For example, a fatal crash can involve multiple fatalities and injuries. The value of crash costs per event and crash costs per crash were calculated in accordance with NDOT Performance Management Report and the details are provided in *Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, October 2018*. Table 5 provides the crash costs used in the estimation of safety benefits.

Table 5: Monetary Value of Crash Severity

Crash Severity	Crash Cost (2018$/event)	Crash Cost (2018$/crash)
Fatal (K)	$6,000,000	$6,600,000
Severe Injury (A)	$317,600	$476,636
Moderate Injury (B)	$116,100	$186,476
Minor Injury (C)	$65,000	$113,612
PDO	$10,600	$38,200

Source: Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, Oct 2018; Pg F-11; Table 7

The present value of emission reduction savings at a 7% discount rate is $73.6 million for Build Option 1, and $80.6 million for Build Option 2 for the evaluation period of 20 years from year 2021 to 2040.

3.4. Vehicle Operating Cost Savings

Vehicle operating costs include fuel costs and non-fuel costs. Non-fuel costs are operating costs other than fuel savings, which include tires, depreciation, maintenance, insurance, license, registration, taxes and financing.

The per-mile vehicle operating cost estimates were multiplied by the difference between the annualized VMT under the No-Action and Build options. Fuel cost savings, and operating costs other than fuel savings (non-fuel costs) are explained in subsequent sections.

3.4.1. Fuel Cost Savings

Fuel costs vary with speed, fuel consumption rates and fuel prices. The per-mile fuel cost estimates as shown in Table 6 were multiplied by the difference between the annualized VMT under the No-Action and Build options with fuel consumption rates and fuel prices.

Table 6: Vehicle Operating Costs per-mile, Cars and Trucks (2018$)

Item	Auto	Truck
Fuel Cost (Excludes Tax) ($/Gallon)	$ 3.05	$ 2.85
Non Fuel Cost ($/Mile)	$ 0.291	$ 0.474

Source: Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, Oct 2018; Pg F-8; Table 4

The project will result in fuel cost savings due to improved flow of traffic. While VMT does increase network-wide, there is a reduction in fuel consumption due to improved speeds because of reduced congestion. Fuel consumption rates for average operating speed were obtained from "California Air Resources Board, EMFAC 2014 through 2050 average" used by Cal-B/C Model. Fuel price for automobiles and trucks were based on Las Vegas metro average fuel prices, which is retrieved from the AAA gas prices webpage. The details of fuel consumption rates used and estimation of fuel costs for autos and trucks are provided in *Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, October 2018, Page F-7, Table 3*.

The present value at a 7% discount rate from fuel cost savings from year 2021 to 2040 is $39.1 million for Build Option 1 and $40.7 million for Build Option 2.

3.4.2. Operating Costs other than Fuel Savings

Change in VMT will result in changes in non-fuel operating costs. The cost estimation details shown in Table 6 for non-fuel vehicle operating costs per-mile for cars and truck is provided in *Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, October 2018*. These costs are applied to the increased VMT that results from the project improvements. These are negative benefit or "disbenefits" associated with the project.

The USDOT "Benefit-Cost Analysis Guidance for Discretionary Grant Programs" provides the vehicle operating items to include for autos and trucks. It should be noted that fuel costs are calculated separately in this analysis. For autos, non-fuel vehicle operating costs include maintenance, tires, and depreciation. For trucks, truck/trailer lease or purchase payments, repair and maintenance, insurance, license, registration, and tires are included.

The present value of non-fuel operating costs at a 7% discount rate resulting in disbenefits of ($26.5) million for Build Option 1, and ($20.8) million for Build Option 2 for the evaluation period of 20 years from year 2021 to 2040.

The present value of net vehicle operating costs savings including Fuel and non-fuel costs at a 7% discount rate from year 2021 to 2040 is $12.6 million for Build Option 1, and $19.9 million for Build Option 2.

3.5. CO_2 and Other Emission Reduction Savings

Vehicle emissions are associated negatively with health effects and costs. Vehicle emissions are estimated based on average vehicle operating speeds and VMT. Emission rates associated with vehicle speeds were obtained from "Environmental Protection Agency's Motor Vehicle Emission Simulator (version MOVES2014a)" for Clark County, Nevada. These emission rates were collected for all relevant pollutants (volatile organic compounds [VOC], nitrogen oxide [NOx], particulate matter [PM], sulfur dioxide [SO2], and carbon dioxide [CO2]) for 5 mile increment speed bins, for years 2020 and 2040, and for autos and trucks vehicle types from *Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, October 2018*. The emission values in Short Ton are then monetized into health costs using Table 7. The monetary values were utilized from SNTS BCA, based on Tables A-6 and A-7 in the USDOT's Benefit-Cost Analysis Guidance for Discretionary Grant Programs. Per SNTS BCA, USDOT does not currently recommend unit values for reduction in CO_2.

It is anticipated that the project improvements will result in a net reduction of emissions. While VMT does increase network-wide, there is a reduction in emissions due to improved speeds and reduced idling.

Table 7: Monetary values for Emission Types (2018$)

Emission Type	Cost/Short Ton
Volatile Organic Compounds (VOCs)	$ 1,941
Nitrogen oxides (NOx)	$ 7,649
Particulate matter ($PM_{2.5}$)	$349,872
Sulphur dioxide (SO_2)	$ 45,204
Carbon dioxide (CO_2)	$ 0

Source: Appendix F Benefit Cost Analysis of Southern Nevada Traffic Study Final Report, Oct 2018; Pg F-9; Table 5

The present value of emission reduction savings at a 7% discount rate is $0.5 million for Build Option 1 and $0.7 million for Build Option 2 for the evaluation period of 20 years from year 2021 to 2040.

4. BENEFIT-COST ANALYSIS RESULTS

A summary of the project's benefits and costs (in 2018 $) is shown in Table 8 for Build Option1 and Build Option 2. As indicated, the present value of net benefits is $702.0 million with B/C ratio of 3.78 for Build Option 1, and $721.6 million with B/C ratio of 4.18 for Build Option 2. The detail tabulation of present value of B/C at 7% discount rate is shown in Table 9 for Build Option 1, and in Table 10 for Build Option 2.

Table 8: Summary of Benefits and Costs, (2018$, Present Value at 7% Real Discount Rate)

Measures	Build Option 1	Build Option 2
Benefits (and Disbenefits)		
Travel Time Savings (mil. $)	$867.6	$847.3
Crash Reduction Savings (mil. $)	$73.6	$80.6
Vehicle Operating Cost Savings (mil. $)	$12.6	$19.9
Fuel Cost Savings (mil. $)	$39.1	$40.7
Other Operating Cost Savings (mil. $)	($26.5)	($20.8)
CO_2 and other Emission Reduction Savings (mil. $)	$0.5	$0.7
Life-Cycle Benefits (mil. $)	**$954.2**	**$948.5**
Life-Cycle Costs (mil. $)	**$252.2**	**$226.9**
Net Present Value (mil. $)	**$702.0**	**$721.6**
Benefit/Cost Ratio	**3.78**	**4.18**

Table 9: Present value of Benefits and Costs by Year (2018$, 7% Real Discount Rate) – Build Option 1

Year	Travel Time Savings	Crash reduction savings	Vehicle Operating Cost savings	Vehicle emission reduction benefits	Present Value of Total Benefits	Design and Construction Costs	Roadway and Bridge O&M	Net Present Value
2020	0	0	0	0	0	244,485,981	0	(244,485,981)
2021	$72,021,978	$5,095,198	$1,042,391	$74,781	$78,234,348	0	$679,710	$77,554,638
2022	$67,886,720	$4,940,433	$982,540	$70,488	$73,880,181	0	$635,243	$73,244,938
2023	$63,984,281	$4,784,112	$926,059	$66,436	$69,760,887	0	$593,685	$69,167,202
2024	$60,301,896	$4,627,100	$872,763	$62,612	$65,864,371	0	$554,846	$65,309,525
2025	$56,827,475	$4,470,156	$822,477	$59,005	$62,179,112	0	$518,548	$61,660,565
2026	$53,549,568	$4,313,943	$775,035	$55,601	$58,694,148	0	$484,624	$58,209,524
2027	$50,457,333	$4,159,038	$730,281	$52,391	$55,399,042	0	$452,919	$54,946,123
2028	$47,540,506	$4,005,938	$688,065	$4,018	$52,238,527	0	$423,289	$51,815,237
2029	$44,789,370	$3,855,069	$648,247	$3,786	$49,296,472	0	$395,597	$48,900,874
2030	$42,194,729	$3,706,796	$610,694	$3,566	$46,515,785	0	$369,717	$46,146,068
2031	$39,747,882	$3,561,423	$575,280	$3,360	$43,887,946	0	$345,530	$43,542,415
2032	$37,440,597	$3,419,207	$541,886	$3,165	$41,404,855	0	$322,925	$41,081,930
2033	$35,265,084	$3,280,356	$510,400	$2,981	$39,058,821	0	$301,799	$38,757,021
2034	$33,213,978	$3,145,039	$480,713	$2,807	$36,842,538	0	$282,055	$36,560,482
2035	$31,280,311	$3,013,388	$452,727	$2,644	$34,749,070	0	$263,603	$34,485,466
2036	$29,457,497	$2,885,502	$426,345	$2,490	$32,771,833	0	$246,358	$32,525,475
2037	$27,739,306	$2,761,451	$401,477	$2,345	$30,904,579	0	$230,241	$30,674,338
2038	$26,119,852	$2,641,282	$378,039	$2,208	$29,141,381	0	$215,179	$28,926,202
2039	$24,593,569	$2,525,017	$355,948	$2,079	$27,476,614	0	$201,102	$27,275,512
2040	$23,155,198	$2,412,661	$335,130	$1,957	$25,904,946	0	$187,945	$25,717,001
Total	$867,567,131	$73,603,109	$12,556,498	$478,718	$954,205,455	$269,260,956	$7,704,918	$702,014,556

Table 10: Present Value of Benefits and Costs by Year (2018$, 7% Real Discount Rate) – Build Option 2

Year	Travel Time Savings	Crash reduction savings	Vehicle Operating Cost savings	Vehicle emission reduction benefits	Present Value of Total Benefits	Design and Construction Costs	Roadway and Bridge O&M	Net Present Value
2020	0	0	0	0	0	222,242,991	0	($222,242,991)
2021	$70,341,914	$6,270,894	$1,648,895	$104,404	$78,366,108	0	$412,705	$77,953,402
2022	$66,303,119	$5,967,830	$1,554,221	$98,410	$73,923,580	0	$385,706	$73,537,874
2023	$62,491,712	$5,677,580	$1,464,877	$92,753	$69,726,923	0	$360,473	$69,366,450
2024	$58,895,227	$5,399,766	$1,380,572	$87,415	$65,762,979	0	$336,890	$65,426,089
2025	$55,501,854	$5,134,002	$1,301,027	$82,378	$62,019,261	0	$314,851	$61,704,410
2026	$52,300,412	$4,879,900	$1,225,982	$77,626	$58,483,920	0	$294,253	$58,189,667
2027	$49,280,310	$4,637,073	$1,155,187	$73,144	$55,145,714	0	$275,003	$54,870,711
2028	$46,431,524	$4,405,132	$1,088,408	$8,714	$51,933,778	0	$257,012	$51,676,766
2029	$43,744,563	$4,183,693	$1,025,423	$8,210	$48,961,889	0	$240,198	$48,721,691
2030	$41,210,448	$3,972,374	$966,020	$7,735	$46,156,577	0	$224,484	$45,932,092
2031	$38,820,679	$3,770,798	$910,001	$7,286	$43,508,765	0	$209,798	$43,298,966
2032	$36,567,216	$3,578,596	$857,177	$6,863	$41,009,852	0	$196,073	$40,813,779
2033	$34,442,452	$3,395,403	$807,371	$6,464	$38,651,689	0	$183,246	$38,468,443
2034	$32,439,191	$3,220,863	$760,412	$6,088	$36,426,555	0	$171,258	$36,255,297
2035	$30,550,632	$3,054,629	$716,142	$5,734	$34,327,136	0	$160,054	$34,167,082
2036	$28,770,338	$2,896,360	$674,410	$5,400	$32,346,508	0	$149,583	$32,196,925
2037	$27,092,229	$2,745,726	$635,073	$5,085	$30,478,112	0	$139,797	$30,338,315
2038	$25,510,552	$2,602,405	$597,997	$4,788	$28,715,741	0	$130,652	$28,585,089
2039	$24,019,873	$2,466,085	$563,053	$4,508	$27,053,519	0	$122,105	$26,931,414
2040	$22,615,054	$2,336,463	$530,123	$4,244	$25,485,885	0	$114,116	$25,371,768
Total	$847,329,299	$80,595,571	$19,862,370	$697,250	$948,484,490	$243,648,954	$4,678,257	$721,563,242

5. SENSITIVITY ANALYSIS

The BCA described above is based on a real discount rate of 7% as recommended.[1] A real discount rate is a discount rate that reflects the opportunity cost of money net of the rate of inflation.[2] The same reference also encourage a sensitivity analysis using a discount rate of 3%.

Table 11 shows sensitivity of the costs and benefits relative to a discount rate of 3% for both Build options. The B/C ratio changed from 3.78 to 5.31 for Build Option 1, and from 4.18 to 5.88 for Build Option 2 which implies that additional potential benefits may occur.

Table 11: Sensitivity Analysis (2018$)

	Build Option 1		Build Option 2	
	7%	3%	7%	3%
Life-Cycle Costs	$252.2 M	$265.2 M	$226.9 M	$237.7 M
Life-Cycle Benefits	$954.2 M	$1,408.3 M	$948.5 M	$1,398.2 M
Net Present Value	$702.0 M	$1,143.0 M	$721.6 M	$1,160.5 M
Benefit/Cost Ratio	3.78	5.31	4.18	5.88

[1] *Office of Management and Budget (OMB) Circular A-94: "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs." October 29, 1992.*

[2] *"TIGER Discretionary Grants; Appendix A: Additional Information on Benefit-Cost Analysis; Discounting." Federal Register 76:156, August 12, 2011, pp 50305.*

6. CONCLUSION

The B/C for the Henderson Interchange feasibility study is 3.78 for Build Option 1 and 4.18 for Build Option 2 with a 7% discount rate. The project is overall a good return on investment, attributable to reduction in congestion combined with an increase in safety and capacity. The primary contribution is from travel time savings, and the secondary from crash, vehicle operating cost, and emissions savings. It should be noted that this BCA shows the cost effectiveness of an investment due to the fact that each dollar invested in this project will result in user benefits of $3.78 or $4.18.