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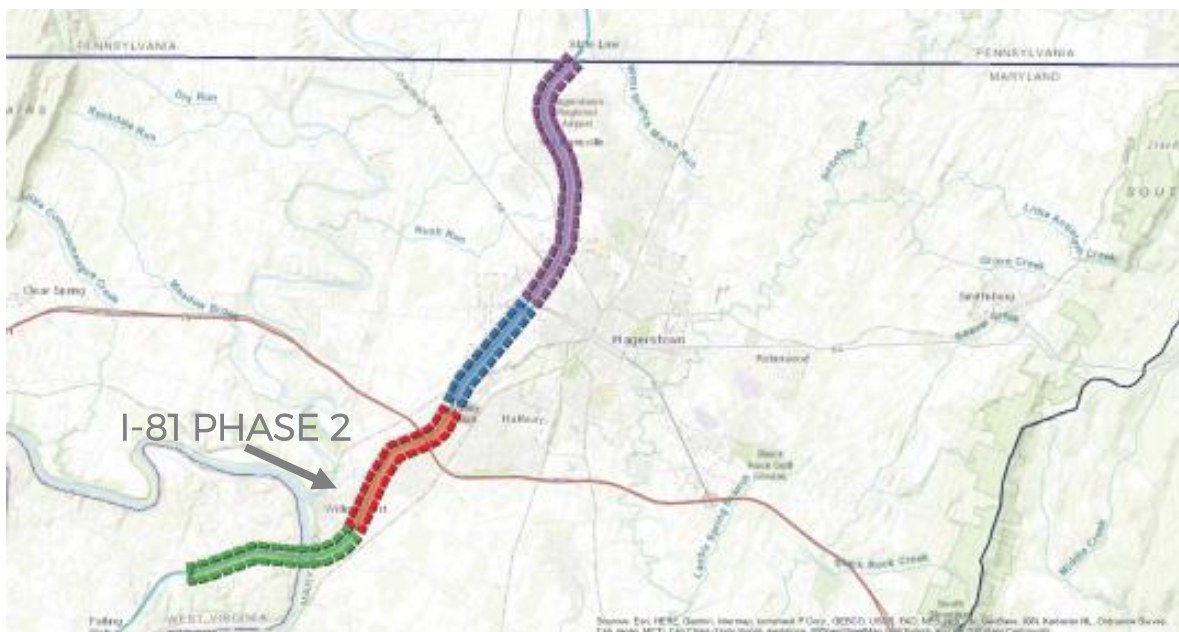
I-81 PHASE 2 CORRIDOR EXPANSION:

MAKING WAY FOR ECONOMIC GROWTH AND SAFETY

BENEFIT-COST ANALYSIS SUPPLEMENTARY
DOCUMENTATION

*FY 2018 BUILD DISCRETIONARY GRANT
PROGRAM*

Prepared for: Maryland Department of Transportation State Highway Administration

MDOT
MARYLAND DEPARTMENT
OF TRANSPORTATION
STATE HIGHWAY
ADMINISTRATION

July 19, 2018

Executive Summary

A benefit-cost analysis (BCA) was conducted for the Interstate 81 Phase 2 Corridor Expansion: Making Way for Economic Growth and Safety ("I-81 Phase 2," "the project") in Maryland, for submission to the U.S. Department of Transportation (U.S. DOT) as a requirement of a discretionary grant application for the BUILD 2018 program. The analysis was conducted in accordance with the benefit-cost methodology, values, and assumptions specified by U.S. DOT in the 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs document.[1]

The Maryland Department of Transportation State Highway Administration (MDOT SHA) is advancing the project as part of a larger, four-phase expansion of I-81 along its entire length in the State of Maryland, from the Pennsylvania to West Virginia state lines. The broader project, which consists of widening the current I-81 from four to six lanes, and improvements to substandard exit and entry ramps, represents a continuation of improvements already made to I-81 in West Virginia to the south. It would enhance critical highway connections both to the West Virginia border, as well as to the Pennsylvania border. The expansion of I-81 is crucial to address existing conditions and, particularly, to accommodate growing freight demand that is slated to double along the corridor by 2040.

Improvements associated with Phase 1 improvements, which include significant costs to widen and improve the Potomac River Bridge, are fully funded and currently under construction (see the Project Overview below and Figures 1 and 2). This BUILD application therefore seeks funding to support I-81 Phase 2 improvements; as a result, and in accordance with feedback received from U.S. DOT following the FY 2017 INFRA grant application, this BCA has been conducted for I-81 Phase 2 improvements only. Although this narrow approach demonstrates that substantial economic benefits are expected to result from the I-81 Phase 2 improvements, the analysis likely understates the full magnitude of benefits that are likely to be generated by the full four-phase project.

A critical element of the larger program that will solve many transportation problems on its own, I-81 Phase 2 is a relatively short segment of 3.5 miles; as a result, the benefits of the proposed project would not be fully realized without all four phases in place. In addition, isolating discrete I-81 Phase 2 benefits from a travel-demand modeling perspective involved the creation of a future condition that is unlikely to exist—that is, a future in which only the project elements associated with Phase 2 are constructed. Consequently, the results of that modeling describe a future roadway condition that is not planned or anticipated.

Benefits and costs in this BCA are phased in accordance with the expenditures associated with I-81 Phase 2 improvements. The BCA therefore reflects the best estimates of when costs would be incurred to build the project, as well as when incremental benefits associated with the project would start to be realized. The analysis period for discounting spans 2018 through 2044; this

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[1] U.S. Department of Transportation. 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs. 2018.

interval includes the construction of I-81 Phase 2, and extends for thirty years of project operation starting in 2025, when the project is assumed to be operational.

Project Overview

The I-81 Phase 2 scope includes the construction of two new lanes of travel (one southbound and one northbound), reconstruction activities, and improvements at three interchanges along a 3.5-mile segment of I-81 within Washington County, Maryland, extending from 2,000 feet north of MD 63/MD 68 to 1,000 feet north of Halfway Boulevard. Six travel lanes and reconstructed interchange configurations will significantly increase capacity for freight volumes, enhance traffic operations, and improve safety; therefore, I-81 Phase 2 will result in improved safety, increased mobility for the region's rural population, and accommodate freight tonnage that is expected to increase roughly 70 percent over the next 25 years. I-81 Phase 2 project is the critical link of the overall expansion project, which will ultimately modernize the interstate and capitalize on the expansion project recently completed in West Virginia.

Figure ES-1. I-81 Improvement Project in Maryland – Location Map

Figure 5: Phase 2 Corridor Expansion in Comparison to I-81 between Knoxville and Canada
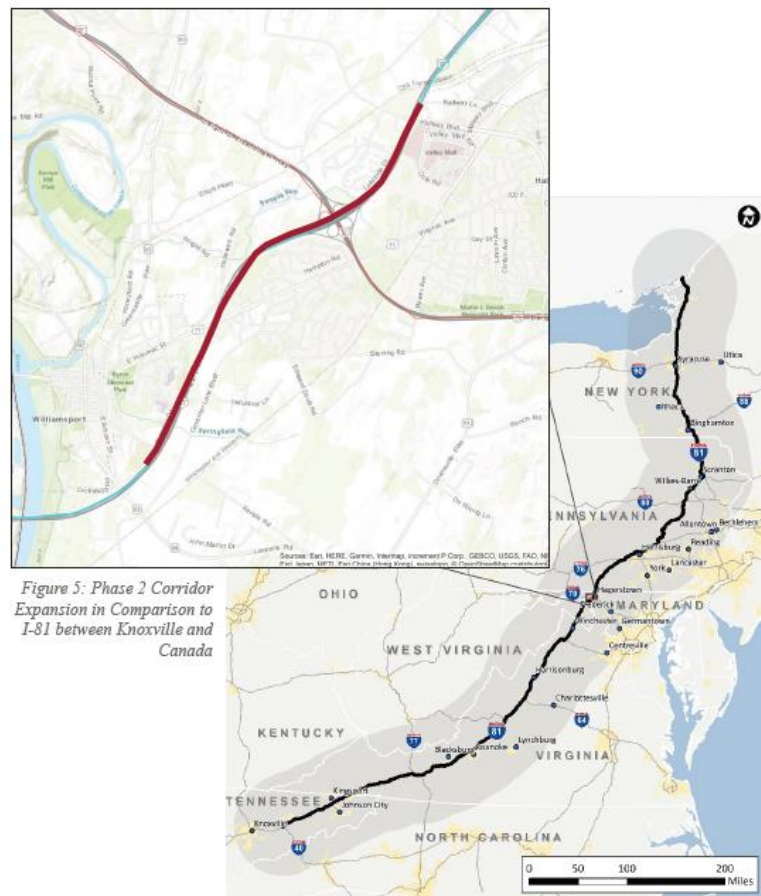
Figure ES-2. Project Phases
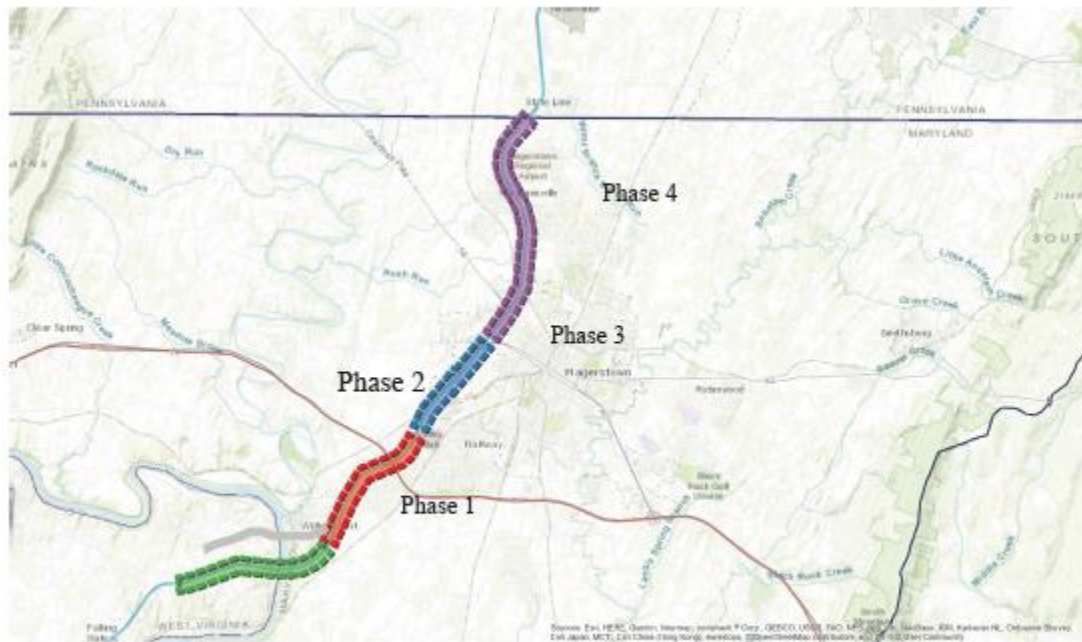
Table ES-3. Project Phase Details

Project Phase	Miles	Project Limits/Description
Phase 1 (Funded and under construction)	1.3	North of US 11 (WV) to north of MD 63/68. Widening and interchange improvements at MD 68/MD 63.
Phase 2 (BUILD Request)	3.5	2,000' North of MD 63/MD 68 to 1000' North of Halfway Boulevard. Includes widening and three interchange improvements at US 11, I-70 and Halfway Boulevard.
Phase 3 (Unfunded)	2.0	1000' North of Halfway Boulevard to US 40. Includes widening and one interchange improvement US 40.
Phase 4 (Unfunded)	5.3	US 40 to PA 163 (State line). Includes widening and four interchange improvements at MD 58, Maugansville Road, Maugans Avenue, Showalter Road, and PA 163.

Estimated Project Costs

The following costs are included in the BCA:

- Capital costs
- Annual incremental maintenance costs
- Residual Value (negative cost offset)

Capital Cost

Estimated capital costs for I-81 Phase 2 are shown below in Table ES-4. Phase 1 costs are *not* included, as they have been previously incurred or committed, and are treated as a sunk cost for decision-making.

Table ES-4: Project Capital Costs and Construction Timing

Variable	Unit	Value
Phase 2 (Undiscounted)		
Construction Start	year	2020
Construction End	year	2024
Project Opening	year	2025
Capital Cost	2017$	$76,759,921

Source: MDOT SHA

Annual Maintenance Costs

Maintenance costs have been estimated based on an assumed per lane mile cost of $10,000. This is a conservative (high) value, compared with the range of values seen in the research literature, and identified through other planning studies conducted by the BCA study team. For example, the Victoria Transport Policy Institute, in its Benefit Cost Analysis guidance reports a cost per lane mile for routine maintenance of $4,400 in 2004 (based on Texas DOT data); in 2017 dollars, this translates to approximately $5,600 per lane mile.[2] Estimated maintenance costs are shown in Table ES-5.

Consistent with U.S. DOT's 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, maintenance costs have been grouped with other project costs in this report, but were included in the numerator for purposes of calculating the benefit-cost ratio.

Year	Additional Lane Miles	Annual Undiscounted O&M Cost (2017$)
2025 (Phase 2)	7.0	$70,000

Source: WSP estimate

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[2] Victoria Transport Policy Institute, Transportation Cost and Benefit Analysis II – Roadway Costs, retrieved from http://www.vtpi.org/tca/tca0506.pdf

Rehabilitation Cost

It is anticipated that a one-time rehabilitation cost will be incurred at the midpoint of the project's useful life. Because the project's useful life is 50 years, the mid-life rehabilitation will take place after the analysis period, which only covers 20 years of project operations. Therefore, no rehabilitation costs have been assumed for the project.

Estimated Benefits

Two broad categories of monetizable benefits have been captured in the BCA: anticipated travel benefits from increased operational capacity and performance, and anticipated safety benefits from reduced crashes. In addition, the residual value of the project at the conclusion of the analysis period is considered a project benefit. These are described below.

Travel Benefits/Travel Time Savings

Within this category, two discrete benefit estimates were made:

- The value of travel time savings for highway users (auto and commercial-vehicle operations) resulting from increased capacity;
- Additional travel time savings from reduced incident delays (auto and commercial-vehicle operations); in this case, only crash-related incident delays were considered. As described further in this report and in more detail in the grant application, the project is expected to have major impacts on safety, based on compelling evidence from the similarly improved I-81 in West Virginia, greatly reducing the unusually high number of serious crashes including fatalities consistently observed over the past four years.

These benefits account for approximately 1.3 percent of the project's total monetized benefits.

Safety Benefits

Over and above the travel time benefits from reduced crashes, the monetized benefits of crash avoidance in terms of property damage, injury, and loss of life are a substantial project benefit. Based on the observed percentage reduction in crashes of all types over the four years since the I-81 widening in West Virginia, significant comparable crash reductions are also anticipated in Maryland. Those reductions will result in direct and very sizeable economic savings. In particular, a significant share of those benefits will be from reductions in fatal crashes, which have occurred at a striking frequency in recent years – twice the statewide average along I-81 in Maryland.

These benefits account for approximately 93 percent of the project's total monetized benefits.

Residual Value

The analysis period covered by the BCA includes 20 years of operation, beginning in 2025. (It also includes costs that will be incurred prior to 2025 for I-81 Phase 2 construction). For purposes of the analysis, a high quality interstate improvement is assumed to have an average useful life of 50 years. Using straight line depreciation, a residual value of 60 percent of the cost is assumed

at the end of 2044, or $39.7 million in 2018 dollars. The discounted value is $6.8 million at 7 percent.

This benefit accounts for approximately 5.3 percent of the project's total monetized benefits.

Benefits Summary

Benefits are summarized in Table ES-6, categorized by long term outcome, and showing the basis of benefits estimation. The details of these estimates, and the BCA in general, are contained in the body of the BCA Report and in accompanying spreadsheets provided to support the application.

Table ES-6: Project Benefits by Long-Term Outcome Category

Long-Term Outcome	Basis for Benefit	Benefit Category	Discounted at 7%, 2017$
Economic Competitiveness	• Passenger Travel Time Savings - PHT reductions	50,0000 annual PHT saved by 2040,	$5.1 M
	• Crash related incident delays reduced by 40%	Reduced PHT and Truck VHT based on INRIX daily delay data and known major crashes on I-81 12,260 vehicle hours of incident delay saved, 2040	$1.8 M
Safety	• Vehicle crash reductions based on expansion from 4 to 6 lanes and reconstruction of hazardous exit and entry ramps • 40% reduction based on West Virginia data	Reduced Highway Crashes: 86 fewer crashes per year in 2040 including at least one fewer fatality	$121.4 M
State of Good Repair	• Not monetized but interchange improvements will replace or rebuild older interchanges not designed to best modern standards	Not quantified	
Residual Value	• Remaining asset value following the analysis period		$6.8 M
TOTAL			$130 M

Source: WSP

Benefit Cost Results

The results of the BCA are summarized in Table ES-7. The Net Present Value (NPV) of the project over the full analysis period through 2044 is $71.3 million at a 7 percent discount rate in 2017 dollars, and the Benefit Cost Ratio (BCR) is 2.23; at a 3 percent discount rate, the results are an NPV of $15.6 million and a BCR of 3.50.

Table ES-7. BCA Results

Case	Net Present Value (2017$)	Benefit-Cost Ratio
Case A: **7% Discount Rate**	$71.3 M	2.23
Case B: **3% Discount Rate**	$159.6 M	3.50

Source: WSP

Contents

1. Introduction

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A critical element of the larger program that will solve many transportation problems on its own, I-81 Phase 2 is a relatively short segment of 3.5 miles; as a result, the benefits of the proposed project would not be fully realized without all four phases in place. In addition, isolating discrete I-81 Phase 2 benefits from a travel-demand modeling perspective involved the creation of a future condition that is unlikely to exist—that is, a future in which only the project elements associated with Phase 2 are constructed. Consequently, the results of that modeling describe a future roadway condition that is not planned or anticipated.

Benefits and costs in this BCA are phased in accordance with the expenditures associated with I-81 Phase 2 improvements. The BCA therefore reflects the best estimates of when costs would be incurred to build the project, as well as when incremental benefits associated with the project would start to be realized. The analysis period for discounting spans 2018 through 2044; this interval includes the construction of I-81 Phase 2, and extends for thirty years of project operation starting in 2025, when the project is assumed to be operational.

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[3] U.S. Department of Transportation. 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs. 2018.

Report Contents

- Section 2 of this report provides a project overview
- Section 3 describes the general BCA assumptions.
- Section 4 describes the project costs including initial investment costs, and operating, maintenance, and other life-cycle costs.
- Section 5 describes the project benefits, including a summary of benefits, and provides details on the factors and assumptions used to derive benefits for each benefit type
- Section 6 provides details on the unit values and other assumptions used to monetize project benefits
- Section 6 summarizes the results of the benefit-cost analysis and sensitivity analysis to assess the impacts of changes in key estimating assumptions.

2.   Project Overview

The I-81 Phase 2 scope includes the construction of two new lanes of travel (one southbound and one northbound), reconstruction activities, and improvements at three interchanges along a 3.5-mile segment of I-81 within Washington County, Maryland, extending from 2,000 feet north of MD 63/MD 68 to 1,000 feet north of Halfway Boulevard. Six travel lanes and reconstructed interchange configurations will significantly increase capacity for freight volumes, enhance traffic operations, and improve safety; therefore, I-81 Phase 2 will result in improved safety, increased mobility for the region's rural population, and accommodate freight tonnage that is expected to increase roughly 70 percent over the next 25 years. I-81 Phase 2 is the critical link of the overall expansion project, which will ultimately modernize the interstate and capitalize on the expansion project recently completed in West Virginia.

Figure 2-1. I-81 Improvement Project in Maryland - Location Map
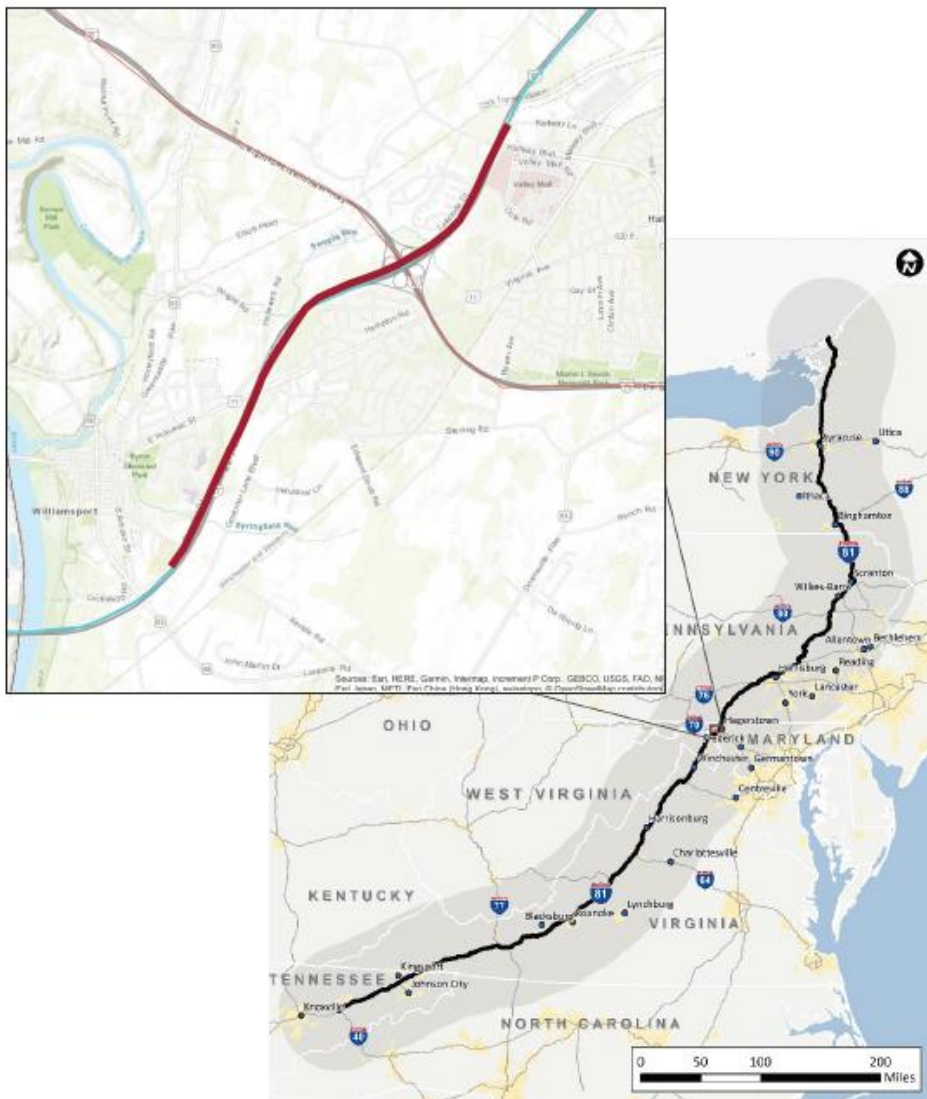
Figure 2-2. Project Phases
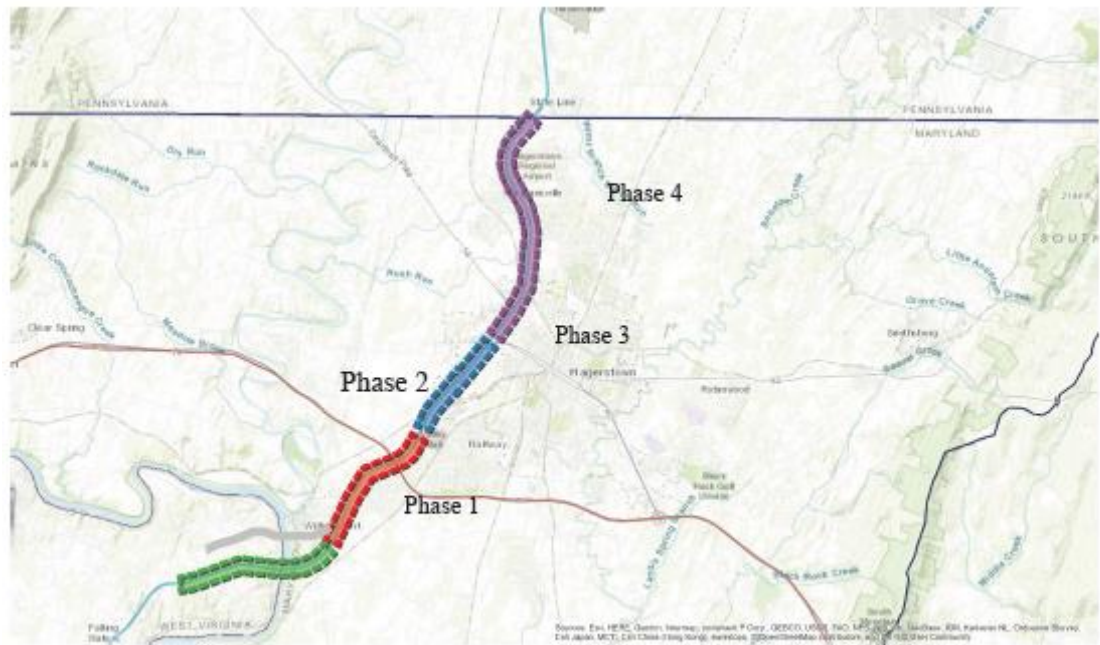
Table 2-1. Project Phase Details

Project Phase	Miles	Project Limits/Description
Phase 1 (Funded and under construction)	1.3	North of US 11 (WV) to north of MD 63/68. Widening and interchange improvements at MD 68/MD 63.
Phase 2 (BUILD Request)	3.5	2,000' North of MD 63/MD 68 to 1000' North of Halfway Boulevard. Includes widening and three interchange improvements at US 11, I-70 and Halfway Boulevard.
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3. General BCA Assumptions

3.1 Benefit-Cost Evaluation Measures

The benefit-cost analysis converts potential gains (benefits) and losses (costs) from the project into monetary units and compares them. The following two common benefit-cost evaluation measures are included in this BCA.

- **Net Present Value (NPV):** NPV compares the net benefits (benefits minus costs) after being discounted to present values using the real discount rate assumption. The NPV provides a perspective on the overall dollar magnitude of cash flows over time in today's dollar terms.
- **Benefit Cost (B/C) Ratio:** The evaluation also estimates the benefit-cost ratio; the present value of incremental benefits is divided by the present value of incremental costs to yield the benefit-cost ratio. The B/C ratio expresses the relation of discounted benefits to discounted costs as a measure of the extent to which a project's benefits either exceed or fall short of their associated costs. Consistent with U.S. DOT's 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, maintenance costs have been grouped with other project costs in this report, but were included in the numerator for purposes of calculating the benefit-cost ratio.

3.3 Discounting and Real Dollar Valuations

Dollar figures in this analysis are expressed in constant 2017 dollars. In instances where certain cost estimates or benefit valuations were expressed in dollar values in other (historical) years, the U.S. Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) was used to adjust them.[4] All Present Value cost and benefit streams are discounted to 2018, consistent with BUILD program guidance.

The real discount rate used for this analysis is 7.0 percent, consistent with U.S. DOT guidance for BUILD grants and OMB Circular A-4. An alternative BCA modeling run was also made using a 3.0 percent discount rate applicable to all benefits and costs; the lower discount rate may be justified on two counts: 1) to the extent that project funding reduces future consumption, rather than investment, a lower discount rate may be merited to reflect the lower opportunity cost associated with foregone consumption; and 2) to reflect a more nuanced social rate of time preference for future versus short term economic enhancements. However, the 7.0 percent rate is primary in this BCA analysis.

3.4 Evaluation Period

Benefits and costs in this BCA are phased in accordance with the expenditures associated with I-81 Phase 2 improvements. The BCA therefore reflects the best estimates of when costs would

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[4] U.S. Bureau of Labor Statistics. Consumer Price Index, All Urban Consumers, U.S. City Average, Series CUSR0000SA0. 1982-1984=100

be incurred to build the project, as well as when incremental benefits associated with the project would start to be realized. The analysis period for discounting spans 2018 through 2044; this interval includes construction of I-81 Phase 2, and extends for thirty years of project operation starting in 2025, when the project is assumed to be operational.

All benefits and costs are assumed to occur at the end of each year.

4. Project Costs

The following costs are included in the BCA:

- Capital costs
- Annual incremental maintenance costs
- Residual value (negative cost offset)

4.1   Capital Cost

Estimated capital costs for I-81 Phase 2 are shown below in Table 4-1. Phase 1 costs are *not* included, as they have been previously incurred or committed, and are treated as a sunk cost for decision-making.

Table 4-1: Project Capital Costs and Construction Timing

Variable	Unit	Value
Phase 2 (Undiscounted)		
Construction Start	year	2020
Construction End	year	2024
Project Opening	year	2025
Capital Cost	2017$	$76,759,921

Source: MDOT SHA

4.2   Annual Maintenance Costs

Maintenance costs have been estimated based on an assumed per lane mile cost of $10,000. This is a conservative (high) value, compared with the range of values seen in the research literature, and identified through other planning studies conducted by the BCA study team. For example, the Victoria Transport Policy Institute, in its Benefit Cost Analysis guidance[5] reports a cost per lane mile for routine maintenance of $4,400 in 2004 (based on Texas DOT data); in 2017 dollars, this translates to approximately $5,600 per lane mile. Estimated maintenance costs for selected years are shown in Table 4-2.

Consistent with U.S. DOT's 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, maintenance costs have been grouped with other project costs in this report, but were included in the numerator for purposes of calculating the benefit-cost ratio.

Table 4-2. Maintenance Costs for Selected Years

Year	Additional Lane Miles	Annual Undiscounted O&M Cost (2017$)
2025 (Phase 2)	7.0	$70,000

Source: WSP Estimate

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[5] Victoria Transport Policy Institute, Transportation Cost and Benefit Analysis II – Roadway Costs, retrieved from http://www.vtpi.org/tca/tca0506.pdf

4.3 Rehabilitation Cost

It is anticipated that a one-time rehabilitation cost will be incurred at the midpoint of the project's useful life. Because the project's useful life is 50 years, the mid-life rehabilitation will take place after the analysis period, which only covers 20 years of project operations. Therefore, no rehabilitation costs have been assumed for the project.

5. Project Benefits

5.1 Overview

Two broad categories of monetizable benefits have been captured in the BCA: anticipated travel benefits from increased operational capacity and performance; and anticipated safety benefits from reduced crashes.

1. Within the first category of travel benefits, two discrete benefit estimates were made:
   - The value of travel time savings for highway users (auto and commercial-vehicle operations) resulting from increased capacity;
   - Additional travel time savings from reduced incident delays (auto and commercial-vehicle operations); in this case, only crash related incident delays were considered. As described further in this report and in more detail in the grant application, the project is expected to have major impacts on safety, based on compelling evidence from the similarly improved I-81 in West Virginia, greatly reducing the unusually high number of serious crashes including fatalities consistently observed over the past four years.

2. The second broad category is safety benefits resulting from reduced crashes; benefits here include various cost savings related to property damage, personal injury, loss of income, and insurance costs.

5.2 Travel Benefits/Travel Time Savings

5.2.1 Travel Time Savings from Capacity Increase

Travel time savings have been derived in the BCA based on travel demand modeling conducted by MDOT SHA to support the BUILD application. Table 5-1 and Table 5-2 show the projected changes in ADT along I-81 and overall network changes in PHT and VMT in 2040, relative to the No Build scenario, for I-81 Phase 2.

Table 5-1. Traffic Forecasts, No Build and Build

Roadway Sections (South to North)	2016 Existing Average Daily Traffic (vehicles) *Lowest - Highest*	2040 No Build Average Daily Traffic (vehicles) *Lowest - Highest*	2040 Phase 2 Average Daily Traffic (vehicles) *Lowest – Highest* (% Increase from No Build)
West Virginia State Line to MD 68	66,500	94,800	103,900 (+9.5%)
MD 68 to I-70	66,800-73,900	95,000-104,700	104,000-113,800 (+8.5% to +9.5%)
I-70 to US 40	81,800-86,100	104,300-110,800	106,100-114,000 (+2% to +3%)
US 40 to Pennsylvania State Line	60,700-77,200	75,900-95,600	75,900-96,000 (No change to +0.5%)

Source: MDOT SHA

Table 5-2. Projected Daily VMT, VHT, PHT vs. Existing and No-Build

		Auto			Truck			Total		
Scenario	**Year**	**VMT**	**VHT**	**PHT**	**VMT**	**VHT**	**PHT**	**VMT**	**VHT**	**PHT**
Existing	2016	1,603,010	31,099	46,026	330,207	5,000	5,000	1,933,217	36,098	51,026
No Build	2040	2,064,563	43,133	63,836	370,448	6,410	6,410	2,435,011	49,543	70,246
Phase 2 (Opening Day)	2025	1,762,567	35,157	52,033	344,758	5,488	5,488	2,107,325	40,645	57,521
Phase 2 Only	2040	2,087,022	42,955	63,574	381,198	6,546	6,546	2,468,220	49,502	70,120

Source: MDOT SHA

As seen in Table 5-2, daily PHT are reduced for passenger vehicles, while trucks are expected to experience a slight increase. These changes, both negative and positive, are annualized in the BCA using a factor of 310. Linear interpolation was used to derive travel time savings estimates for years between horizon years, as well as for years following the 2040 model year. Table 5-2 indicates a small increase in VMT on a regionwide basis compared with the No-Build. This is likely due to some route shifting and/or induced trips, to take advantage of the increased capacity and faster travel times on I-81, rather than induced growth in the regional transportation network. These impacts are assumed to be minor from a BCA standpoint as they do not reflect a change in mode share but rather an adaption to take advantage of the improved conditions on I-81, relative both to the No Action condition and to other facilities in the network.

Travel time savings are valued in the BCA utilizing the 2018 BUILD guidance for passenger value of time. Truck driver wage savings, which vary with truck hours saved, are also estimated based on hourly rates prescribed by the 2018 BUILD guidance.

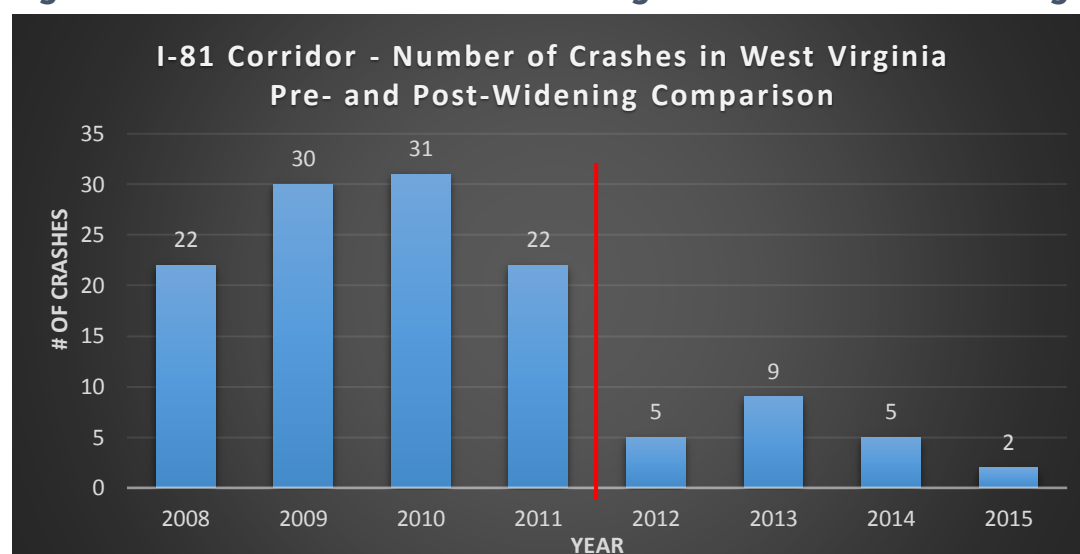## 5.2.3 Travel Time Savings from Reduced Incident Delay

A second type of travel time benefit derives from the reduction in crashes that is projected (see 5.3 discussion). In addition to the much more significant benefits of reduced crashes themselves (including fatal crashes), reduced crashes can save substantial time – delays that can stretch into hours. To estimate those savings, a sizeable database of daily traffic information, from 2014 through October 2016, was examined. Among the indicators in the database are daily delay hours for passengers and trucks. By matching daily delay hours to the dates of known serious crashes, it was possible to estimate an average annual (crash-related) delay. Several of these incident delays exhibited delay hours that were ten times the norm for a typical day. This process is shown graphically in Figure 5-1, which graphs delay hours from INRIX, a global analytics firm that passively collects data from in-vehicle GPS units, and labels those dates when serious crashes occurred.

To derive the value of incident delay reductions, it is assumed that major incidents causing significant delay (such as those shown in Figure 5-1) would fall by 40 percent, consistent with U.S. DOT guidance following submission of the previous INFRA grant application. Figure 5-2 shows an average annual decrease in crashes of 80 percent after a similar widening along I-81 in West Virginia, indicating that the 40 percent estimate is likely conservative. The 40 percent reduction in incident delay is then monetized using the values of time for truck and passenger vehicles.

Figure 5-1. INRIX Daily Vehicle Hours of Delay and Major Crashes
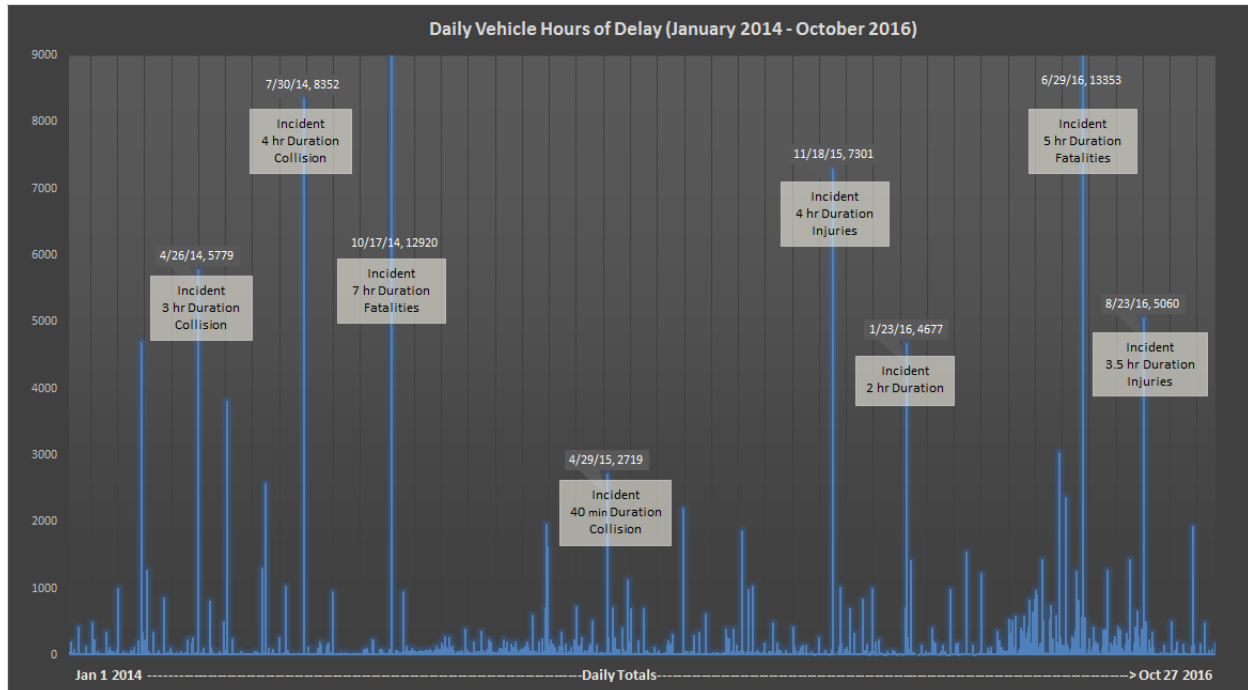
Figure 5-2. Number of Crashes in West Virginia Pre- and Post-Widening

I-81 Corridor - Number of Crashes in West Virginia Pre- and Post-Widening Comparison

Source: MDOT SHA

Annual incident-related delay savings for selected years are shown in Table 5-3. Incident delays are valued at the same values per hour for trucks and passengers as were applied to travel time savings from capacity increases.

Table 5-3. Annual Incident Delay Savings for Selected Years

Year	Auto PHT	Truck PHT	Undiscounted 2017$
2025	7,000	3,000	$210,000
2030	7,600	3,200	$240,000
2035	8,100	3,400	$270,000
2040	8,700	3,600	$300,000

Source: WSP

5.3   Safety Benefits

Based on the 80 percent reduction in crashes of all types observed over the four years since the I-81 widening in West Virginia (see Figure 5-2), significant comparable crash reductions are also anticipated in Maryland. Based on guidance provided by U.S. DOT following the 2017 INFRA grant application, a crash-modification factor (CMF) for I-81 Phase 2 of 40 percent was assumed for this BUILD application. That CMF indicates that the expected number of crashes in the project area will be reduced by 40 percent following the project's opening. It is expected that this CMF underestimates the likely magnitude of crash-related benefits, as demonstrated by the impacts resulting from recent interventions along I-81 in West Virginia.

The magnitude of that reduction was calculated by determining the historical crash rates on the existing facility, using data for 2010 through 2016 furnished by MDOT SHA. For these years, the number of crashes—including those resulting in a fatality, injury, or property damage—was compared to the total VMT for the facility; those crash rates were then applied to the travel demand forecasts discussed in the previous section to determine the potential number of crashes in future years. The expected 40 percent reduction was then applied to future year values, which were then compared to the expected number of crashes in the No Action condition, which were also estimated using the travel demand forecasts discussed previously.

Based on this analysis, I-81 Phase 2 will result in substantial direct economic benefits. In particular, a significant share of those benefits will be from reductions in fatal crashes, which, as noted in the application narrative, have occurred at a striking frequency – twice the statewide average (Table 5-4) along I-81 in Maryland.

Table 5-4: Historic I-81 Crash Data

	2010	2011	2012	2013	2014	2015	2016	Total
Total Crashes	66	72	87	88	113	122	118	666
Property Damage (PDO) Crashes	33	39	51	49	67	82	86	407
Injury Crashes	31	32	34	37	44	40	31	249
Injuries (Persons)	49	52	58	52	61	64	56	392
Fatal Crashes	2	1	2	2	2	-	1	10
Fatalities (Persons)	2	1	2	2	3	-	1	11
Truck Crashes	18	12	23	25	46	35	29	27
VMT (Millions)[6]	265.90	262.80	248.50	258.60	258.50	299.20	316.10	1,910
Crash Rate (per Million VMT)	0.25	0.27	0.35	0.34	0.44	0.41	0.37	0.35
Fatal Crash Rate (per Million VMT)	0.01	0.00	0.01	0.01	0.01	-	0.00	0.01
Injury Crash Rate (per Million VMT)	0.12	0.12	0.14	0.14	0.17	0.13	0.10	0.13
PDO Crash Rate (per Million VMT)	0.12	0.15	0.21	0.19	0.26	0.27	0.27	0.21
Truck Crash Rate (per Million VMT)	0.07	0.05	0.09	0.10	0.18	0.12	0.09	0.01

Source: MDOT SHA

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[6] The VMT figures reported in this table were derived from crash reporting provided by MDOT SHA and may not align with facility-level travel-demand modeling. As a result, they are used only to calculate crash rates, and not for purposes of forecasting expected facility-level VMTs.

Estimated reductions in crashes and corresponding crash savings are shown in Table 5-5 for selected years. Crash reductions are valued based on 2018 BUILD guidance.

Table 5-5. Crash Reductions for Selected Years

	Projected Number of Crashes Reduced Annually				Crash Savings, Undiscounted (2017$)
	All Crashes	**PDO Crashes**	**Injuries (Persons)**	**Fatalities (Persons)**	
2025	74.4	46.8	42.5	1.1	$16.0
2030	78.1	49.1	44.6	1.2	$16.8
2035	81.9	51.5	46.8	1.3	$17.6
2040	85.8	54.0	49.1	1.3	$18.5

Source: WSP, based on MDOT SHA data

5.4 Residual Value

The analysis period covered by the BCA includes 20 years of operation, beginning in 2025. (It also includes costs that will be incurred prior to 2025 for I-81 Phase 2 construction). For purposes of the analysis, a high-quality interstate improvement is assumed to have an average useful life of 50 years. Using straight line depreciation, a residual value of 60 percent of the cost is assumed at the end of 2044, or $39.7 million in 2018 dollars. The discounted value is $6.8 million at 7 percent.

5.5 Benefits Summary

Benefits are summarized in Table 5-6, categorized by long term outcome, and showing the basis of benefits estimation. The details of these estimates, and the BCA in general, are contained in accompanying spread sheets provided to support the application.

Table 5-6: Project Benefits by Long-Term Outcome Category

Long-Term Outcome	Basis for Benefit	Benefit Category	Discounted at 7%, 2017$
Economic Competitiveness	• Passenger Travel Time Savings - PHT reductions	50,0000 annual PHT saved by 2040	$5.1 M
	• Crash related incident delays reduced by 40%	Reduced PHT and Truck VHT based on INRIX daily delay data and known major crashes on I-81 12,260 vehicle hours of incident delay saved, 2040	$1.8 M
Safety	• Vehicle crash reductions based on expansion from 4 to 6 lanes and reconstruction of hazardous exit and entry ramps • 40% reduction based on West Virginia data	Reduced Highway Crashes: 86 fewer crashes per year in 2040 including at least one fewer fatality	$121.4 M

State of Good Repair	• Not monetized but interchange improvements will replace or rebuild older interchanges not designed to best modern standards	Not quantified	
Residual Value	• Remaining asset value following the analysis period		$6.8 M
TOTAL			$130 M

Source: WSP

6. Unit Values and Methodology Details

6.1 Economic Competitiveness - Travel Time Savings

As noted, travel time benefits appearing in this analysis include auto passenger time savings, due to faster speeds from increased capacity, which are offset somewhat by slight delays in truck traffic; and travel-time savings for autos and trucks resulting also from reduced incident delays arising from fewer crashes.

6.1.1 Hourly Value of Time – Personal Travel/Auto Users

Passenger time savings are based on PHT reductions. The hourly value of time values are summarized below in Table 6-1. Values of time are increased in real terms at a rate of 1.2 percent per year.

Table 6-1: Hourly Value per Hour – Auto Truck Driver Costs (2017$ / hour)

	2025	2030	2035	2040
Cost per Hour - Personal Travel	$16.24	$17.24	$18.30	$19.43

Source: U.S. DOT INFRA Guidance

6.1.2 Truck Variable Operating Cost Savings – Vehicle Operators

Truck driver savings are based on reduced delays caused by crashes on the facility, which are expected to be reduced by I-81 Phase 2. These savings are offset somewhat by anticipated delays for truck traffic in the With Action condition. The hourly value of time values for truck drivers are summarized in Table 6-2. Driver wages are increased in real terms at a rate of 1.2 percent per year.

Table 6-2: Hourly Truck Driver Costs (2017$ / hour)

	2025	2030	2035	2040
Cost per Hour - Truck Operators	$31.46	$33.40	$35.45	$37.63

Source: U.S. DOT INFRA Guidance

6.2 Safety Benefits - Crash Cost Savings

The cost savings that arise from a reduction in the number of crashes include direct savings (e.g., reduced personal medical expenses, lost wages, and lower individual insurance premiums), as well as significant avoided costs to society (e.g., second party medical and litigation fees, emergency response costs, incident congestion costs, and litigation costs). The value of all such benefits – both direct and societal – could also be approximated by the cost of service disruptions to other travelers, emergency response costs to the region, medical costs, litigation costs, vehicle damages, and economic productivity loss due to workers' inactivity.

Table 6-3 shows the number of crashes reduced due to the project, for selected years. Linear interpolation was used to estimate crash reductions in intermediate years.

Table 6-3: Crashes Avoided (Rounded), Selected Years

	2025	2030	2035	2040
Crashes Avoided	74	78	82	86

To monetize these crash savings, it was first necessary to convert injury crashes into the Abbreviated Injury Scale (AIS). For this, WSP utilized national statistics from the National Highway Traffic and Safety Administration[7] to derive the distribution of total injuries into their respective AIS categories, as indicated in the following table which lists each AIS category as a proportion of all possible injuries.

Table 6-4: U.S. AIS Categories as Proportion of All Non-Fatal Injuries.

Injury Type	Proportion
AIS 5	0.18%
AIS 4	0.69%
AIS 3	2.39%
AIS 2	8.28%
AIS 1	88.46%
All Injuries	100%

Source: NHTSA

Monetized values for fatalities, and crashes categorized on the AIS scale are reported in the 2017 "Benefit-Cost Analysis Guidance for TIGER and INFRA Applications," as shown in Table 6-5.

Table 6-5: Monetized Crash Values

Crash Type	Unit Value (2017$)
Fatality	$9,600,000
AIS 5	$5,692,800
AIS 4	$2,553,600
AIS 3	$1,008,000
AIS 2	$451,200
AIS 1	$28,800
Property Damage Only	$4,327

Source: U.S. DOT, 2018 BUILD Guidance

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[7] National Highway Traffic Safety Administration (2002), The Economic Impact of Motor Vehicle Crashes, 2000, p. 9, Table 3 "Incidence Summary – 2000 Total Reported and Unreported Injuries."

7. BCA Results

7.1 Results at Alternative Discount Rates

The results of the BCA are summarized in Table 7-1; summary results by year over the full analysis period are shown in A-1. The Net Present Value (NPV) of the project over the full analysis period through 2044 is $71.3 million at a 7 percent discount rate in 2017 dollars, and the Benefit Cost Ratio (BCR) is 2.23; at a 3 percent discount rate, the results are an NPV of $383.2 million and a BCR of 2.55.

Consistent with U.S. DOT's 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, maintenance costs have been grouped with other project costs in this report, but were included in the numerator for purposes of calculating the benefit-cost ratio.

Table 7-1. BCA Results

	7% Discount Rate (2017$)	3% Discount Rate (2017$)
Economic Competitiveness		
Travel Time Savings (Including Incident Delay Savings)	$1.73 M	$3.15 M
Safety		
All Safety Benefits	$121.4 M	$216.8 M
Residual Value	$6.83 M	$18.4 M
TOTAL PV BENEFITS	$130.0 M	$238.4 M
PRESENT VALUE, COSTS (all phases)		
Capital	$58.2 M	$67.9 M
Maintenance	$0.49 M	$0.87 M
TOTAL PV COSTS	$58.7 M	$68.8 M
NET PRESENT VALUE	$71.3 M	$169.6 M
BENEFIT-COST RATIO	2.23	3.50

Source: WSP

7.2 Sensitivity Tests

7.2.1 Crash Reductions

The results obtained and shown in Table 7-1 are sensitive to the input assumptions. Based on a scan of the key variables, it is felt that the major risk variable is the number of crashes. To gauge the range of BCA results for reasonable downward variations in this assumption, results are presented below for the following alternative assumptions for the CMF:

- 30 percent fewer crashes are avoided as a result of the project, relative to the base case assumption of 40 percent

- 20 percent fewer crashes are avoided as a result of the project, relative to the base case assumption of 40 percent

As shown in Table 7-2 and Table 7-3, I-81 Phase 2 would generate economic benefits under both alternative assumptions for the rate at which the project would reduce crashes along the facility.

Table 7-2: Sensitivity Analysis, 30% Reduction in Crashes Avoided

	Net Present Value (2017$)	Benefit Cost Ratio
7% discount rate	$40.2 M	1.69
3% discount rate	$113.9 M	2.68

Source: WSP

Table 7-3: Sensitivity Analysis, 20% Reduction in Crashes Avoided

	Net Present Value (2017$)	Benefit Cost Ratio
7% discount rate	$8.96 M	1.15
3% discount rate	$58.0 M	1.85

Source: WSP

Appendix A1 – Cumulative Benefits and Costs, by Year, 7% Discount Rate