

APPENDIX B: BENEFIT-COST ANALYSIS

**Benefit-Cost Analysis Supplementary
Documentation**

BUILD Transportation Discretionary Grant
Program

I-95 at Belvidere Road Interchange

*Cecil County, MD in partnership with Maryland Department
of Transportation (MDOT), Maryland Transportation
Authority (MDTA) and Stewart Companies*

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Benefit-Cost Analysis Supplementary Documentation

1. Executive Summary

I-95/Belvidere Road Interchange (Proposed Interchange) in Cecil County, Maryland, provides potential for improved safety, economic growth and development, and improved transportation and infrastructure. The Proposed Interchange is a public-private partnership between Cecil County, the Maryland Department of Transportation Maryland Transportation Authority (MDOT MDTA), and The Stewart Companies of York, Pennsylvania (SC). MDOT MDTA owns and maintains I-95 in Cecil County and an affiliate of SC, is the owner of the Principio Business Park (PBP) as well as 6,610 acres in the immediate vicinity of the Proposed Interchange.

Cecil County has identified the Proposed Interchange as the key to unlocking the full economic potential of the Cecil County Principio Enterprise Zone (CCPEZ). The Proposed Interchange would immediately support existing PBP tenants/occupants that feature large market cap companies including Amazon, General Electric (GE), Medline and LIDL, among others. The Proposed Interchange would attract new businesses and help maintain the sustainability of existing businesses by reducing energy and operating costs that are essential to the warehousing and distribution industry.

A table summarizing the changes expected from the project (and the associated benefits, discounted at 7 percent) is provided below.

Table ES-1: Summary of Infrastructure Improvements and Associated Benefits

Current Status or Baseline & Problems to Be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Population Affected by Impacts	Benefits	Summary of Results (millions of \$2017)	Page #
High crash rates along US 40, MD 222, and MD 272	Proposed Interchange to redirect vehicle traffic to and from Principio Business Park (PBP)	Reduced crashes involving cars and heavy trucks	Vehicles traveling to/from the PBP and on US 40, MD 222, and MD 272	Accident Cost Reduction Benefits	\$6.6	18
Roadway congestion along heavily trafficked local roads	Proposed Interchange to redirect vehicle traffic to and from PBP	Reduced travel distance and delay for vehicle traffic	Vehicles traveling to/from the PBP and on US 40, MD 222, and MD 272	Travel Time Savings	\$51.9	24
Roadway congestion along heavily trafficked local roads	Proposed Interchange to redirect vehicle traffic to and from PBP	Reduced travel distance and out-of-pocket operating costs for vehicle traffic	Vehicles traveling to/from the PBP and on US 40, MD 222, and MD 272	Out-of-Pocket Vehicle Operating Cost Savings	\$27.4	24
Roadway congestion along	Proposed Interchange to	Reduced vehicle miles traveled on	Residents and workers in the	Emission Cost Reduction Savings	\$1.2	28



Current Status or Baseline & Problems to Be Addressed	Changes to Baseline / Alternatives	Type of Impacts	Population Affected by Impacts	Benefits	Summary of Results (millions of \$2017)	Page #
heavily trafficked local roads	redirect vehicle traffic to and from PBP	local roads	project vicinity (PBP, US 40, MD 222, and MD 272)			
Degrading pavement condition on US 40, MD 222, and MD 272 due to heavy traffic	Proposed Interchange to redirect vehicle traffic to and from PBP	Reduced vehicle traffic on local roads	Local agencies charged with roadway maintenance	Pavement Maintenance Cost Savings	\$1.5	22
Traffic diverting to Proposed Interchange	Increased roadway mileage to maintain due to Proposed Interchange	Increase in operation and maintenance costs	Local agencies charged with roadway maintenance	Operation & Maintenance Cost (Disbenefit)	(\$5.4)	22

The period of analysis used in the estimation of benefits and costs corresponds to 26 years, including 6 years of pre-construction and construction activity and 20 years of operation. The total (undiscounted) project costs are \$54.0 million dollars according to the distribution shown in Table ES-2.

Table ES-2: Summary of Project Costs, in Millions of Dollars of 2017

Cost Category	Undiscounted Project Cost	Percentage of Undiscounted Project Cost
Capital Costs	\$48.4	89.6%
Right of Way Acquisition	\$5.6	10.4%
TOTAL COST	\$54.0	100.0%

There are also annual maintenance and operation (O&M) costs attributed to the Proposed Interchange, which would begin to accrue in the first year of operation and continue for the entire study period. This is considered the incremental O&M costs between the No Build and the Build scenarios. O&M cost for the Proposed Interchange is \$715,203 per year, and total undiscounted O&M costs for the entire study period amount to \$14.3 million.

A summary of the relevant data and calculations used to derive the benefits and costs of the project are shown in the Benefit-Cost Analysis (BCA) model (in dollars of 2017). Based on the analysis presented in the rest of this document, the project is expected to generate \$83.2 million in discounted benefits and \$44.8 million in discounted costs, using a 7 percent real discount rate. Therefore, the project is expected to generate a Net Present Value of \$38.4 million and a Benefit/Cost Ratio of 1.9.

In addition to the monetized benefits, the project would generate benefits that are difficult to quantify. A brief description of those benefits is provided below.

Economic Competitiveness

- **Inventory Cost Savings:** The Proposed Interchange will significantly impact traffic related to the Principio Business Park (PBP), including freight truck trips in connection with the distribution centers located there. The reduction in trip length and congestion in the various routes to and from the PBP will generate inventory cost savings for these freight movements. Given the lack of a standardized methodology to monetize these benefits, they were not included in this BCA.
- **Improved Mobility:** Without making any improvements, the I-95/MD 222 interchange, along with seven study area intersections, will operate at undesirable levels-of-service with the projected 2040 full-build-out of the CCPEZ and planned adjacent development. The Proposed Interchange will improve access and mobility to PBP and the surrounding area. In an effort to be conservative in the BCA, the model does not quantify this effect.
- **Economic Development:** Coinciding with improved mobility, the Proposed Interchange provides increased access to the area with significant potential for future economic development, making it a desirable location for future developers. It is expected that the Proposed Interchange will accelerate the development at PBP and the surrounding area, which will have positive economic impacts on the local and regional economy. In an effort to be conservative in the BCA, the model does not quantify this effect.

Environmental Protection

- **Potential environmental mitigation opportunities:** The public-private partnership will identify land that has the capacity to provide compensatory mitigation to any project impacts, and land may be identified to be utilized for environmental stewardship and/or future mitigation needs. Additionally, the footprint of the Proposed Interchange is currently zoned for mineral extraction. Mineral extraction activities would almost certainly affect greater natural resource impact than the Proposed Interchange. The extent of these environmental impacts are unknown, and thus left unquantified in this analysis.

Quality of Life

- **Improved quality of life from less truck traffic:** Local residents and workers will benefit from the reduction of heavy truck vehicles around the US 40 intersections with MD 222 and MD 272. People who continue to use US 40, MD 222, and MD 272 after the Proposed Interchange is complete may accrue benefit from lower noise levels and an improved driving experience on these roads. In an effort to be conservative in the BCA, the model does not quantify this improvement.
- **Access to more jobs:** The project would contribute to the attraction of more businesses and generate economic development opportunities for the local community. In this rural area, the attraction of new businesses, the development of employment opportunities, and the provision of access to these jobs can improve the quality of life for Cecil County residents in several ways.

Innovation

- **Diverging Diamond Interchange (DDI) design as an option:** DDI is one of the interchange options being proposed to meet the transportation needs of the area. This innovative design has proven effective across the country in reducing accidents and it would be the first full DDI in Maryland.
- **Design-Build Project Delivery:** Cecil County may save months in the project schedule through a design-build project delivery, which allows the engineer and contract team

opportunities to innovate in design and construction. In an effort to be conservative, the model does not monetize this effect.

- **Innovative Financing:** Use of innovative financing by having project stakeholders Cecil County, the Maryland Department of Transportation Maryland Transportation Authority (MDOT MDTA), and The Stewart Companies of York, Pennsylvania (SC) provide all the planning, design, construction and right-of-way to complete this project.

Partnership

- **Public-Private Partnership:** The Proposed Interchange project has brought together three strong partners: Cecil County, the Maryland Department of Transportation Maryland Transportation Authority (MDOT MDTA), and The Stewart Companies of York, Pennsylvania (SC), to achieve goals of economic development and improved mobility in this rural area of western Cecil County, Maryland. This is a tremendous opportunity for a predominantly rural county to team with a state transportation agency to use a significant percentage of private non-federal money and deliver a project that will increase job opportunities in an area that has logistically demonstrated its ability to achieve Cecil County's economic goals and vision.

Non-Federal Revenue for Transportation Infrastructure Improvement

- **Toll Revenues:** Increased toll revenues for heavy trucks that would be heading northbound to Belvidere Road and would pay a US 40 or I-95 toll.
- **Property Taxes:** Increased taxes for Cecil County in terms of additional property taxes due to the potential development of future commercial areas.

2. Introduction

This document provides detailed technical information on the economic analyses conducted in support of the grant application for the I-95 at Belvidere Road Interchange project.

Section 3, Methodological Framework, introduces the conceptual framework used in the BCA. Section 4, Project Overview, 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 that the I-95 at Belvidere Road Interchange is expected to generate. Section 5, General Assumptions, discusses the general assumptions used in the estimation of project costs and benefits, while estimates of travel demand and traffic growth can be found in Section 6, Demand Projections. Specific data elements and assumptions pertaining to the long-term outcome selection criteria are presented in Section 7, Benefits Measurement, Data and Assumptions, along with associated benefit estimates. Estimates of the project's Net Present Value (NPV), its Benefit/Cost ratio (BCR) and other project evaluation metrics are introduced in Section 8, Summary of Findings and BCA Outcomes. Next, Section 9, BCA Sensitivity Analysis, provides the outcomes of the sensitivity analysis. Additional data tables are provided within the BCA model including annual estimates of benefits and costs to assist the U.S. Department of Transportation (USDOT) in its review of the application.¹

3. Methodological Framework

The BCA conducted for this project includes the monetized benefits and costs measured using USDOT guidance, as well as the quantitative and qualitative merits of the project. A BCA provides estimates of the benefits that are expected to accrue from a project over a specified period and compares them to the anticipated costs of the project. 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 based on the projected impacts of the project on both users and non-users of the facility, valued in monetary terms.²

While BCA is just one of many tools that can be used in making decisions about infrastructure investments, USDOT believes that it provides a useful benchmark from which to evaluate and compare potential transportation investments.³

The specific methodology developed for this application was developed using the BCA guidance developed by USDOT and is consistent with the BUILD program guidelines. In particular, the methodology involves:

- Establishing existing and future conditions under the Build and No Build scenarios;
- Assessing benefits with respect to each of the eight merit criteria identified in the Notice of Funding Opportunity (NOFO);
- Measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement;

¹ While the BCA model does not accompany this appendix, it is provided separately as part of the application.

² USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, June 2018.

³ Ibid.

- Using USDOT guidance for the valuation of travel time savings, safety benefits and reductions in air emissions, while relying on industry best practice for the valuation of other effects;
- Discounting future benefits and costs with the real discount rates recommended by USDOT (7 percent, and 3 percent for sensitivity analysis); and
- Conducting a sensitivity analysis to assess the impacts of changes in key estimating assumptions.

4. Project Overview

I-95 is the foremost north-south roadway in Maryland, providing access to Wilmington, Philadelphia, and points north, and to Baltimore, Washington, D.C. and points south. I-95 also provides direct access to major rail, port, and air facilities along the east coast from Maine to Florida. The project is located in rural western Cecil County, which is traversed by I-95 in an east-west orientation. Belvidere Road crosses over I-95 between the MD 222 interchange to the west and the MD 272 interchange to the east. While Cecil County is predominantly rural, it is a part of the Wilmington Metropolitan Area Planning Council (WILMAPCO) Metropolitan Planning Organization. According to the U.S. Census, the Proposed Interchange Study Area is not in an Urban Area and is therefore considered to be rural.

I-95 is part of the National Highway System, it is functionally classified as an “Interstate” in the Federal Functional Classification System, and it is also included in the State Primary System. US 40, MD 272, MD 222 are all functionally classified as arterials and are owned and maintained by the Maryland Department of Transportation State Highway Administration (MDOT SHA). Belvidere Road and other surrounding roads are functionally classified as collectors and are owned and maintained by Cecil County.

Along I-95, there are approximately 6.6 miles between the MD 222 interchange and the MD 272 interchange. This section of I-95, analyzed in the BCA for the Proposed Interchange, is generally six lanes wide (three 12-foot lanes in each direction), with 10-foot inside and outside shoulders and a 25-foot grass median. Exit 93 (MD 222) and Exit 100 (MD 272) currently provide indirect access between I-95 and businesses along Belvidere Road, including the Principio Business Park (PBP). Belvidere Road is a two-lane road which crosses over I-95 approximately mid-way between the exits for MD 222 and MD 272. The Belvidere Road structure over I-95 is approximately 2.5 miles east of the MD 222 interchange and 4.1 miles west of the MD 272 interchange. US 40 runs approximately parallel to I-95 and intersects MD 222, MD 272, and Belvidere Road. US 40 is generally 4 lanes wide, two 12-foot lanes in each direction, with 10-foot outside shoulders and two-foot inside shoulders with a variable width grass median.

An active CSX railroad line crosses beneath Belvidere Road approximately 0.75 mile south of I-95. A spur from this railroad currently serves the GE Distribution Center and Perryville Cold Storage facility located in the Study Area at the Principio Business Park.

Cecil County in northeastern Maryland is a mostly rural county with just over 100,000 residents. Less than one half of employed Cecil County residents actually work in the county. The remaining employed residents work in neighboring jurisdictions (Maryland Department of Commerce). Economic development within the Proposed Interchange area would provide

residents with employment opportunities in Cecil County that are not currently available, and would serve the rapidly growing logistics and distribution industry along this portion of the I-95 corridor by attracting new businesses and employees to planned development in CCPEZ.

4.1 Base Case and Alternatives

Under the current configuration, the access roads for the PBP are congested with high crash rates with limited potential to enhance and facilitate future economic activity in the area. Trucks and PBP-related traffic will continue to utilize MD 222, MD 272, and US 40 to access the business park. Particular issues in the Base Case to highlight include:

- **Congestion:** The road network immediately surrounding the PBP, which encompasses US 40, MD 222, and MD 272, is not equipped for the expected future development in the area. Congestion and delay will increase, and conditions at the US 40 intersections with MD 222 and MD 272 will worsen with increased truck traffic.
- **High Truck-Related Vehicle Crash Rates:** The intersections of US 40 at MD 222 and MD 272 will continue to exhibit a high percentage of truck-related accidents, which currently exceeds the state average accident rate.
- **Degradation of roadway conditions:** The condition of the roads and intersections will continue to degrade from heavy truck use.
- **Future Mobility Issues:** Without making any improvements, the I-95/MD 222 interchange, along with seven study area intersections, will operate at undesirable levels-of-service with the projected 2040 full-build-out of the CCPEZ and planned adjacent development.

In the Base Case, the I-95 corridor, surrounding arterial roads, and the PBP access roads maintain the current configuration and operational characteristics, thus maintaining the status-quo of congestion and accident rates that is inadequate for the future expected economic development in the area.

In the Build Case, the Proposed Interchange at Belvidere and I-95 would be built and become operational. The diverted truck traffic would enjoy routes more appropriate for freight movement, and traffic both related and unrelated to the PBP would experience reduced congestion and delay. Due to the lower levels of truck traffic on the arterial roads (US 40, MD 222, and MD 272), truck-related accidents would significantly decrease, providing a safer road network.

The Proposed Interchange would immediately support existing PBP tenants/occupants that feature large market cap companies including Amazon, General Electric (GE), Medline and LIDL, among others. The Proposed Interchange would also attract new businesses and help maintain the sustainability of existing businesses by reducing energy and operating costs that are essential to the warehousing and distribution industry.

4.2 Types of Impacts

The purpose of the Proposed Interchange is to safely and efficiently improve vehicular access to I-95 at Belvidere Road to facilitate ongoing and planned economic development in Cecil



County’s CCPEZ Zone and to address the associated increase in traffic volumes along I-95. By improving Belvidere Road access to I-95, several benefits will be realized.

An improved Belvidere Road access to I-95 would significantly remove the number of heavy trucks that operate on US 40, MD 222 and MD 272. The intersections in the study area with high truck-related accident rates that currently exceed the state average accident rate would experience a decrease in the number of accidents due to the reduced traffic.

The current north/south travel path between I-95 and PBP contains 12 traffic signals, which significantly delay the trip and increase fuel consumption resulting from vehicle stops and starts. Traffic traveling to and from PBP and other businesses will benefit from shorter and more direct routes, while the traffic that remains on US 40, MD 222, and MD 272 will benefit from relieved congestion and reduced delay.

Shorter, more direct routes will reduce the vehicle-miles traveled, resulting in reduced energy consumption and costs. Cargo owners will experience inventory cost savings, and decreased miles traveled will reduce air pollution from emissions. Less traffic on US 40, MD 222, and MD 272 will result in reduced pavement maintenance cost for these roads, and the Proposed Interchange will require additional operation & maintenance cost (a disbenefit).

The Proposed Interchange will improve accessibility and mobility in the study area, and will enable the I-95 interchanges and US 40 intersections at MD 222 and MD 272 to operate at an acceptable level-of-service with the projected 2040 traffic and developments. The interchange provides for the expected future economic development, making it a desirable location for future developers. Further, it is expected that the Proposed Interchange will accelerate the development at PBP and the surrounding area. New businesses in Cecil County will benefit the people in this rural area by providing jobs and saving travel time presently spent commuting out-of-county.

4.3 Project Cost and Schedule⁴

The total (undiscounted) estimated project costs of the Proposed Interchange is \$54.0 million, and Table 1 presents the cost breakdown. This does not include any previously incurred expenses.

Table 1. Summary of Project Costs, in Millions of Dollars of 2017

Cost Category	Undiscounted Project Cost	Percentage of Undiscounted Project Cost
Design-Build Construction	\$40.4	74.8%
Preliminary Engineering	\$4.0	7.4%
Construction Administration	\$4.0	7.4%
Right of Way Acquisition	\$5.6	10.4%
TOTAL COST	\$54.0	100.0%

⁴ All cost estimates in this section are in millions of dollars of 2017, discounted to this year using a 7 percent real discount rate.



In addition to capital and ROW costs, there are annual operation & maintenance (O&M) costs in the Build Case for the Proposed Interchange, which are assumed to begin in the first year of operation, and continue until the last year of the study period. Annual operation & maintenance costs amount to \$715,203, undiscounted. Across the study period, total undiscounted operation & maintenance costs amount to \$14.3 million, and is counted as a disbenefit in the BCA.

The project will start pre-construction activities in 2017 and construction will end in 2022, such that the first year of operation is 2023.

4.4 Disruptions Due to Construction

Since the Proposed Interchange is a new construction, it is expected that disruption to normal traffic flows will be minimal.

4.5 Effects on Selection Criteria

The main benefit categories associated with the project are mapped into the eight merit criteria set forth by USDOT in the table below.

Table 2: Benefit Categories and Expected Effects on Selection Criteria

Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
Safety	Safety benefits from diverted traffic	Reduced vehicle accidents from reduced traffic on US 40, MD 222, and MD 272.	Yes		
State of Good Repair	Pavement Maintenance Cost Savings	Reduced maintenance costs from reduced traffic on US 40, MD 222, and MD 272.	Yes		
	O&M Cost (Disbenefit)	Increased maintenance costs from Proposed Interchange.	Yes		
Economic Competitiveness	Travel time savings	Travel time savings due to shorter route through Proposed Interchange.	Yes		
	Out-of-Pocket Vehicle operating cost Savings	Vehicle operating cost savings due to shorter route through Proposed Interchange.	Yes		
	Inventory Cost Savings	Inventory cost savings for cargo owners due to shorter trucks trips.			Yes
	Improved Mobility	Improved access and mobility to Principio Business Park and the surrounding area.			Yes



Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
	Economic Development	Expected to accelerate the development at PBP and the surrounding area.			Yes
Environmental Protection	Reduced Emissions	Reduced emissions due to reduced vehicle congestion and shorter route through Proposed Interchange.	Yes		
	Potential environmental mitigation opportunities	The project will identify land with the capacity to provide compensatory mitigation to any project impacts, and land may be identified to be utilized for environmental stewardship and/or future mitigation needs.			Yes
Quality of Life	Improved quality of life from less truck traffic	Reduction of heavy truck vehicles around the US 40 intersections with MD 222 and 272.			Yes
	Access to more jobs	Attraction of more businesses and generate economic development opportunities.			Yes
Innovation	Option of Diverging Diamond Interchange (DDI) design	DDI design has proven effective across the country in reducing accidents and would be first full DDI in Maryland.			Yes
	Design-Build Project Delivery	Save months in project schedule through a design-build project delivery.			Yes
	Innovative Financing	Public and private stakeholders to provide all the planning, design, construction and right-of-way to complete this project.			Yes
Partnership	Public-Private Partnerships	The Proposed Interchange project has brought together three strong partners: Cecil County, the Maryland Department of Transportation Maryland Transportation Authority (MDOT MDTA), and The Stewart Companies of York, Pennsylvania (SC), to achieve goals of economic development and improved mobility in this rural area of			Yes



Primary Selection Criteria	Benefit or Impact Categories	Description	Monetized	Quantified	Qualitative
		Cecil County, Maryland.			
Non-Federal Revenue for Transportation Infrastructure Improvement	Toll Revenues	Increased toll revenues for heavy trucks that would be heading northbound to Belvidere Road and would pay a US 40 or I-95 toll.			Yes
	Property Taxes	Increased taxes for Cecil County in terms of additional property taxes due to the potential development of future commercial areas.			Yes

5. General Assumptions

The BCA measures benefits against costs throughout a period of analysis beginning at the start of pre-construction and including 20 years of operations.

The monetized benefits and costs are estimated in 2017 dollars with future dollars discounted in compliance with BUILD requirements using a 7 percent real rate, and sensitivity testing at 3 percent.

The methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices are expressed in 2017 dollars;
- The period of analysis begins in 2017 and ends in 2042. It includes project development and construction years (2017 - 2022) and 20 years of operations (2023 - 2042);
- A constant 7 percent real discount rate is assumed throughout the period of analysis. A 3 percent real discount rate is used for sensitivity analysis;
- Opening year demand is an input to the BCA and is assumed to be fully realized in year 2023 (i.e., immediate use of the Proposed Interchange by Principio-Business-Park-related traffic); and
- Unless specified otherwise, the results shown in this document correspond to the effects of the Full Build alternative (the Proposed Interchange at Belvidere Road and I-95).

6. Demand Projections

Demand projections in the context of this BCA correspond to the estimation of the annual number of trips under the No Build and Build scenarios as well as the project-area roads those trips will use under each scenario (i.e., their routing). For conceptual purposes, the number of trips on any given year and any given scenario is broken down into two types: 1) Principio-Business-Park-related trips; and, 2) non-Principio-Business-Park-related trips. The first kind correspond to trips that originate or terminate at the Principio Business Park, while the second



kind corresponds to trips that do not originate or terminate at the Principio Business Park but use the roadways located in the project area. The distinction is important since Principio-Business-Park-related trips are assumed to have a significant diversion from their current routing to the Proposed Interchange at Belvidere Road and I-95 once this infrastructure is built. In particular, Principio-Business-Park-related trips bound for I-95 (either northbound or southbound) are anticipated to switch from using their current route of US 40 and MD 222 or US 40 and MD 272 to the much shorter route of Belvidere Road to merge with I-95 using the Proposed Interchange.

6.1 Methodology

The number of daily total trips and their routing were provided by The Traffic Group for the years 2017 and 2040 under different scenarios, expressed in AADT (see Table 3). The estimates reflect current (2017) traffic and future (2040) traffic related directly to the development of the Principio Business Park, and total future (2040) traffic that accounts for both Principio-Business-Park-related and non-Principio-Business-Park-related traffic. In the case of traffic related directly to the development of the Principio Business Park, the future traffic numbers were generated using a trip generation software that converts square footage of real estate development and type of businesses into number of trips.⁵ In the case of future traffic not related directly to the development of the Principio Business Park, the current (2017) traffic volumes were grown using a 1 percent growth rate to generate future traffic volumes. The daily numbers presented in Table 3 were annualized using a factor of 290 days per year.

Table 3. Demand Forecasts for Roads in Project Area Under Different Scenarios and Years

Route Name	2017 AADT	2017 AADT	1% Regional Growth	1% Regional Growth	Principio Business Full Build Trips		Projected 2040 AADT	
	(SHA Traffic Map)	w/o Principio*	for 23 Years	w/o Principio*	w/o New Interchange	w/New Interchange	w/o New Interchange	w/New Interchange
MD 222	14,142	13,230	3,637	3,402	17,530	0	35,309	17,779
MD 272	22,831	21,919	5,871	5,637	17,530	0	46,232	28,702
US 40	25,762	25,306	6,625	6,508	8,766	8,766	41,153	41,153
Belvidere Rd	---		---		---	35,061	---	35,061
1. Principio Business Park Warehouses (A to Z) - 15,720 ksf, Daily trips - 43,826 (Adjusted Trips rate for Amazon Distribution center and others use ITE-150 Warehousing Trip Generation Rate) 2. 40% of Principio business park trip goes to US 40 - MD 222 - I-95 South, 40% trips go to US 40 - MD 272-I-95 North, 10% trips go US 40 East and 10% trips go to US West. 3. With Proposed Interchange, 80% trips will use Belvidere Rd and Proposed Interchange, 20% remain on US 40. 4. Existing warehouse in Principio Business Park daily trips are already included in 2017 AADT. 5. Since access point location along Belvidere Rd is not available, the trips shown above will be the projected trips at Belvidere Road south of Proposed Interchange.								
* = Estimated by HDR using this table and information on PBP-related traffic for the year 2017.								

Further disaggregation of this traffic between cars and trucks was developed using current and future shares of each vehicle type obtained from preliminary traffic projections provided by The Traffic Group. In particular, the forecasted number of trips for cars and trucks were created

⁵ In addition, actual trip rates for similar Amazon warehouses were used to supplement this software's estimates.



separately for the years 2017 and 2040 based on the predictions presented in Table 3, and volumes between those years were linearly interpolated.

Finally, the traffic forecasts were developed annually by vehicle type (cars and trucks), route (US 40 and MD 222, US 40 and MD 272 or Belvidere Road / I-95) and type of trip (trips related to the Principio Business Park and trips not related to the Principio Business Park) for the No Build and Build scenarios.

6.2 Assumptions

The key assumptions used in the estimation of annual traffic demand and routing under the No Build and Build scenarios and for each vehicle type is presented in the table below.

Table 4: Assumptions Used in the Estimation of Demand

Variable Name	Unit	Value	Source
Share of traffic that is cars, 2017	Percentage	76.4%	The Traffic Group
Share of traffic that is trucks, 2017	Percentage	23.6%	The Traffic Group
Share of traffic that is cars, 2040	Percentage	70.4%	The Traffic Group
Share of traffic that is trucks, 2040	Percentage	29.6%	The Traffic Group
Annual growth rate for trips not related to Principio Business Park	Annual Percentage Growth	1.0%	The Traffic Group
Annualization Factor	Days per Year	290	HDR Assumption validated by the Traffic Group and KCI
Share of trips related to Principio Business Park that go to US 40 - MD 222 - I-95 South, No Build Scenario	Percentage	40.0%	The Traffic Group
Share of trips related to Principio Business Park that go to US 40 - MD 272-I-95 North, No Build Scenario	Percentage	40.0%	The Traffic Group
Share of trips related to Principio Business Park that go to US 40 East and US 40 West, No Build Scenario	Percentage	20.0%	The Traffic Group
Share of trips related to Principio Business Park that use Belvidere Rd and Proposed Interchange, Build Scenario	Percentage	80.0%	The Traffic Group
Share of trips related to Principio Business Park that remain at US 40, Build Scenario	Percentage	20.0%	The Traffic Group

6.3 Demand Projections

The resulting projections for car and truck volumes and their routing are presented in the tables below for the No Build and Build scenarios.

Table 5: Number of Car Trips and Routing Forecasts

	2017	2023 (Year Open to Traffic)	2030	2040
NO BUILD SCENARIO				
Number of car trips, non-Principio-related, NB & SB local (US-40 only), No Build Scenario	5,604,204	5,980,156	6,418,767	7,045,355



	2017	2023 (Year Open to Traffic)	2030	2040
Number of car trips, non-Principio-related, I-95 SB (US-40 & MD-222), No Build Scenario	2,926,610	3,122,938	3,351,986	3,679,199
Number of car trips, non-Principio-related, I-95 NB (US-40 & MD-272), No Build Scenario	4,851,615	5,177,113	5,556,861	6,099,357
Number of car trips, non-Principio-related, I-95 SB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
Number of car trips, non-Principio-related, I-95 NB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
Number of car trips, Principio-related, NB & SB local (US-40 only), No Build Scenario	103,240	543,060	1,056,184	1,789,217
Number of car trips, Principio-related, I-95 SB (US-40 & MD-222), No Build Scenario	206,480	1,086,120	2,112,367	3,578,434
Number of car trips, Principio-related, I-95 NB (US-40 & MD-272), No Build Scenario	206,480	1,086,120	2,112,367	3,578,434
Number of car trips, Principio-related, I-95 SB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
Number of car trips, Principio-related, I-95 NB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
BUILD SCENARIO				
Number of car trips, non-Principio-related, NB & SB local (US-40 only), Build Scenario	5,604,204	5,980,156	6,418,767	7,045,355
Number of car trips, non-Principio-related, I-95 SB (US-40 & MD-222), Build Scenario	2,926,610	3,122,938	3,351,986	3,679,199
Number of car trips, non-Principio-related, I-95 NB (US-40 & MD-272), Build Scenario	4,851,615	5,177,113	5,556,861	6,099,357
Number of car trips, non-Principio-related, I-95 SB (Belvidere Rd. & I-95), Build Scenario	-	-	-	-
Number of car trips, non-Principio-related, I-95 NB (Belvidere Rd. & I-95), Build Scenario	-	-	-	-
Number of car trips, Principio-related, NB & SB local (US-40 only), Build Scenario	103,240	543,060	1,056,184	1,789,217
Number of car trips, Principio-related, I-95 SB (US-40 & MD-222), Build Scenario	206,480	-	-	-
Number of car trips, Principio-related, I-95 NB (US-40 & MD-272), Build Scenario	206,480	-	-	-
Number of car trips, Principio-related, I-95 SB (Belvidere Rd. & I-95), Build Scenario	-	1,086,120	2,112,367	3,578,434
Number of car trips, Principio-related, I-95 NB (Belvidere Rd. & I-95), Build Scenario	-	1,086,120	2,112,367	3,578,434

The forecasted number of car trips for non-Principio-Business-Park-related trips grows at 1 percent per year in both the No Build and Build scenarios. The development of the Principio Business Park in future years means that Principio-Business-Park-related car trips grow at a much faster rate, but the growth is the same for the No Build and Build scenarios. The key difference between the forecasts of car trips in the No Build and Build scenarios is the fact that in the Build scenario all Principio-Business-Park-related trips going to or coming from I-95 switch to the Proposed Interchange.



Table 6: Number of Truck Trips and Routing Forecasts

	2017	In Project Opening Year (2023)	2030	2040
NO BUILD SCENARIO				
Number of truck trips, non-Principio-related, NB & SB local (US-40 only), No Build Scenario	1,731,636	1,847,801	1,983,327	2,176,935
Number of truck trips, non-Principio-related, I-95 SB (US-40 & MD-222), No Build Scenario	904,290	964,953	1,035,726	1,136,831
Number of truck trips, non-Principio-related, I-95 NB (US-40 & MD-272), No Build Scenario	1,499,095	1,599,670	1,717,008	1,884,633
Number of truck trips, non-Principio-related, I-95 SB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
Number of truck trips, non-Principio-related, I-95 NB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
Number of truck trips, Principio-related, NB & SB local (US-40 only), No Build Scenario	31,900	219,932	439,304	752,691
Number of truck trips, Principio-related, I-95 SB (US-40 & MD-222), No Build Scenario	63,800	439,865	878,607	1,505,382
Number of truck trips, Principio-related, I-95 NB (US-40 & MD-272), No Build Scenario	63,800	439,865	878,607	1,505,382
Number of truck trips, Principio-related, I-95 SB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
Number of truck trips, Principio-related, I-95 NB (Belvidere Rd. & I-95), No Build Scenario	-	-	-	-
BUILD SCENARIO				
Number of truck trips, non-Principio-related, NB & SB local (US-40 only), Build Scenario	1,731,636	1,847,801	1,983,327	2,176,935
Number of truck trips, non-Principio-related, I-95 SB (US-40 & MD-222), Build Scenario	904,290	964,953	1,035,726	1,136,831
Number of truck trips, non-Principio-related, I-95 NB (US-40 & MD-272), Build Scenario	1,499,095	1,599,670	1,717,008	1,884,633
Number of truck trips, non-Principio-related, I-95 SB (Belvidere Rd. & I-95), Build Scenario	-	-	-	-
Number of truck trips, non-Principio-related, I-95 NB (Belvidere Rd. & I-95), Build Scenario	-	-	-	-
Number of truck trips, Principio-related, NB & SB local (US-40 only), Build Scenario	31,900	219,932	439,304	752,691
Number of truck trips, Principio-related, I-95 SB (US-40 & MD-222), Build Scenario	63,800	-	-	-
Number of truck trips, Principio-related, I-95 NB (US-40 & MD-272), Build Scenario	63,800	-	-	-
Number of truck trips, Principio-related, I-95 SB (Belvidere Rd. & I-95), Build Scenario	-	439,865	878,607	1,505,382
Number of truck trips, Principio-related, I-95 NB (Belvidere Rd. & I-95), Build Scenario	-	439,865	878,607	1,505,382

The forecasted number of truck trips for non-Principio-Business-Park-related trips also grows at 1 percent per year in both the No Build and Build scenarios. The development of the Principio Business Park in the future years also means that Principio-Business-Park-related truck trips grow at a much faster rate, but the growth is the same for the No Build and Build scenarios. As

in the case of forecasted car trips, the key difference between the forecasts of truck trips in the No Build and Build scenarios is the fact that in the Build scenario all Principio-Business-Park-related trips going to or coming from I-95 switch to the Proposed Interchange.

7. Benefits Measurement, Data and Assumptions

This section describes the measurement approach used for each benefit or impact category identified in Table 2 (Benefit Categories and Expected Effects on Selection Criteria) and provides an overview of the associated methodology, assumptions, and estimates.

7.1 Safety

The proposed project would contribute to promoting USDOT's safety long-term outcome through the reduction of crashes in the project area. In particular, construction of the project will lead car and truck trips to re-route away from interchanges with greater than statewide average crash rates (including US 40 & MD 272, MD 272 & Lums Rd and US 40 & Red Toad Rd) and onto a safer corridor (Belvidere Road and the Proposed Interchange). As a result, accident cost reduction benefits will be generated.

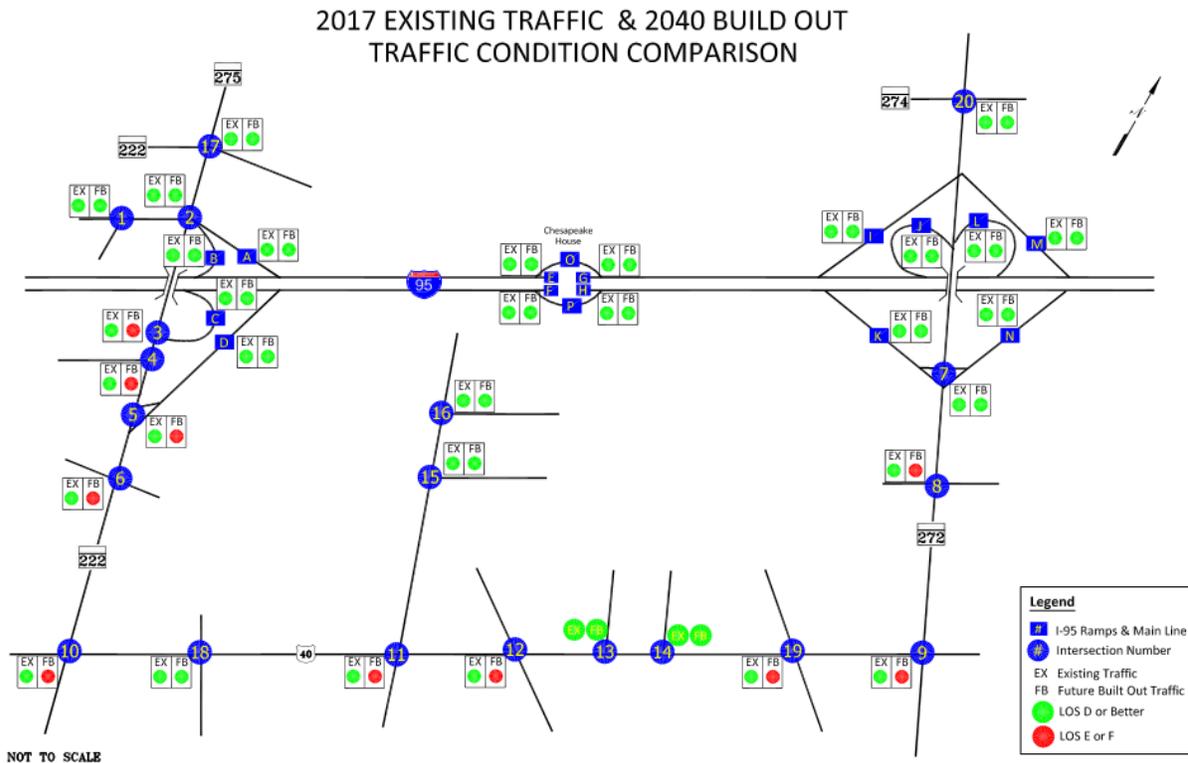
In the Build scenario, Belvidere Road will have less intersections between US 40 and I-95 compared to either MD 222 or MD 272 and therefore the possibility of crashes is reduced for the traffic that uses Belvidere Road to move between I-95 and the Principio Business Park in the Build case.

7.1.1 METHODOLOGY

The methodology to estimate the accident cost reduction benefits relied on the use of historical crash rates at the intersection level in the project area for both the Build and the No Build cases. These rates represent the number of accidents per vehicle moving through the intersection and were obtained by the Traffic Group for the years 2015-2017. The crash rates for the 20 intersections identified in the project area (see figure below) are assumed to be the same in the Build and No Build scenarios and are listed in the assumptions section below.⁶

⁶ The exceptions are intersections 15 (Belvidere Rd & GE Access) and 16 (Belvidere Rd & Cold Food Access) which, due to larger volumes in the Build case, will feature higher crash rates compared to the No Build case. The crash rates for these two intersections in the Build case correspond to the average crash rates of all the intersections in the project area in the No Build case.

Figure 1. Intersections Analyzed in the Project Area



The Proposed Interchange does not currently exist. Therefore, the BCA assumed that the crash rate for this new interchange would be the equivalent of the average between intersections 2 (MD 222 & I-95 SB Ramps), 5 (MD 222 & I-95 NB On Ramp) and 7 (MD 272 & I-95 NB Ramps) depicted in Figure 1.

The demand (in terms of the routing of trips under the Build and No Build scenarios) was used to identify the number of vehicles entering each one of the intersections identified in Figure 1, with the exception of intersections 17 (MD 222 & Bainbridge Rd) and 20 (MD 272 & MD 274) since they are outside of the normal routing of trips between I-95 and the Principio Business Park.⁷ The intersection-level crash rates mentioned above were then combined with the number of vehicles using each intersection under each scenario to estimate the annual number of statistical crashes.

The number of statistical crashes in each year and under each scenario was broken down into the number of accidents with injury and the number of accidents without injury. For those accidents with injury, a further disaggregation was made to identify the number of fatalities, number of incapacitating injuries, number of possible incapacitating injuries and number of non-incapacitating injuries. The breakdown into accidents with and without injury and the further

⁷ Notice that this BCA assumed that only Principio-Business-Park-related trips change their routing due to the Proposed Interchange, and therefore the estimated crash reductions are driven by the number of trips originating from or destined to the Business Park.



breakdown by injury type were based on an analysis of the historical 2015-2017 crash data for all intersections.⁸

The difference in annual crashes by severity type between the Build and No Build scenarios is then monetized using the cost of accidents published by USDOT, discounted appropriately using a 7 percent discount rate and aggregated across the entire period of analysis.

7.1.2 ASSUMPTIONS

The assumptions used in the estimation of accident cost reduction benefits are summarized in the table below.

Table 7: Assumptions Used in the Estimation of Accident Cost Reduction Benefits

Variable Name	Unit	Value	Source
NO BUILD SCENARIO Crash Rates			
1. Turnpike Dr. & Chesapeake Overlook Pkwy	Crashes per Million Vehicles Entering the Intersection	0.00	The Traffic Group
2. MD 222 & I-95 SB Ramps		0.66	The Traffic Group
3. MD 222 & NB Off Ramps		0.07	The Traffic Group
4. MD 222 & Service Rd		0.00	The Traffic Group
5. MD 222 & I-95 NB On Ramp		0.53	The Traffic Group
6. MD 222 & Reservoir Rd		0.30	The Traffic Group
7. MD 272 & I-95 NB Ramps		0.38	The Traffic Group
8. MD 272 & Lums Rd		1.07	The Traffic Group
9. US 40 & MD 272		1.17	The Traffic Group
10. US 40 & MD 222		0.42	The Traffic Group
11. US 40 & Belvidere Rd/MD 7		1.32	The Traffic Group
12. US 40 & MD 7/Old Belvidere Rd		0.26	The Traffic Group
13. US 40 & W. Principio Pkwy		0.06	The Traffic Group
14. US 40 & E. Principio Pkwy/Cold Spring Rd		0.40	The Traffic Group
15. Belvidere Rd & GE Access		0.00	The Traffic Group
16. Belvidere Rd & Cold Food Access		0.00	The Traffic Group
17. MD 222 & Bainbridge Rd		1.02	The Traffic Group
18. US 40 & Coundon Rd		0.32	The Traffic Group
19. US 40 & Red Toad Rd		1.12	The Traffic Group
20. MD 272 & MD 274		0.57	The Traffic Group
BUILD SCENARIO Crash Rates			
1. Turnpike Dr. & Chesapeake Overlook Pkwy	Crashes per Million Vehicles Entering the Intersection	0.00	The Traffic Group
2. MD 222 & I-95 SB Ramps		0.66	The Traffic Group
3. MD 222 & NB Off Ramps		0.07	The Traffic Group
4. MD 222 & Service Rd		0.00	The Traffic Group
5. MD 222 & I-95 NB On Ramp		0.53	The Traffic Group

⁸ The same shares of accidents with injury out of total number of accidents and the shares of injury types for accidents with injuries were assumed for all intersections analyzed, including the Proposed Interchange.



Variable Name	Unit	Value	Source
6. MD 222 & Reservoir Rd		0.30	The Traffic Group
7. MD 272 & I-95 NB Ramps		0.38	The Traffic Group
8. MD 272 & Lums Rd		1.07	The Traffic Group
9. US 40 & MD 272		1.17	The Traffic Group
10. US 40 & MD 222		0.42	The Traffic Group
11. US 40 & Belvidere Rd/MD 7		1.32	The Traffic Group
12. US 40 & MD 7/Old Belvidere Rd		0.26	The Traffic Group
13. US 40 & W. Principio Pkwy		0.06	The Traffic Group
14. US 40 & E. Principio Pkwy/Cold Spring Rd		0.40	The Traffic Group
15. Belvidere Rd & GE Access		0.48	HDR Assumption (average of all intersections in No Build)
16. Belvidere Rd & Cold Food Access		0.48	HDR Assumption (average of all intersections in No Build)
17. MD 222 & Bainbridge Rd		1.02	The Traffic Group
18. US 40 & Coundon Rd		0.32	The Traffic Group
19. US 40 & Red Toad Rd		1.12	The Traffic Group
20. MD 272 & MD 274		0.57	The Traffic Group
Proposed I-95 & Belvidere Rd Interchange		0.52	HDR Assumption (average of I-95 intersections in No Build)
OTHER VARIABLES			
Project-level crash reduction factor for Intersection Design at Belvidere Road and I-95 Intersection	Percentage of total crashes	0.0%	HDR Assumption
Percentage of accidents with injury	Percentage of total crashes	46.8%	HDR Analysis of Historical Crash Data
Average Injuries per Crash (for crashes with injury)	Injuries per Crash (for crashes with injury)	1.57	HDR Analysis of Historical Crash Data
Average Fatalities per Crash (for crashes with injury)	Fatalities per Crash (for crashes with injury)	0.01	HDR Analysis of Historical Crash Data
Percent of Injuries that are Non-incapacitating	Percent of total injuries	34.2%	HDR Analysis of Historical Crash Data
Percent of Injuries that are Possible Incapacitating	Percent of total injuries	58.3%	HDR Analysis of Historical Crash Data



Variable Name	Unit	Value	Source
Percent of Injuries that are Incapacitating	Percent of total injuries	7.5%	HDR Analysis of Historical Crash Data
Cost Of Accident Severity O - No Injury	\$ per injury	\$3,200	USDOT BCA Guidance for BUILD Projects
Cost Of Accident Severity C - Possible Injury	\$ per injury	\$63,900	USDOT BCA Guidance for BUILD Projects
Cost Of Accident Severity B - Non Incapacitating	\$ per injury	\$125,000	USDOT BCA Guidance for BUILD Projects
Cost Of Accident Severity A - Incapacitating	\$ per injury	\$459,100	USDOT BCA Guidance for BUILD Projects
Cost Of Accident Severity K - Killed	\$ per injury	\$9,600,000	USDOT BCA Guidance for BUILD Projects

7.1.3 BENEFIT ESTIMATES

The project is anticipated to reduce the number of accidents in the project area by approximately 170 accident events throughout the entire 20 years of the period of analysis. Of these, 79 will be accidents with injury, which when broken down into severity type represent a little over 1 fatality, 9 incapacitating injuries, 73 possible incapacitating injuries and 43 non-incapacitating injuries.⁹

Table 8: Estimates of Accident Cost Reduction Benefits, Millions of 2017 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Accident Cost Reduction	\$20.08	\$6.60

7.2 State of Good Repair

To quantify the benefits associated with maintaining the existing transportation network in a state of good repair, this BCA focused on two benefit types: 1) pavement maintenance cost reduction for existing roads in the project area; and 2) increased operation and maintenance costs for the Proposed Interchange. The project will generate a reduction in vehicle miles traveled for cars and trucks by providing a more direct route between I-95 and the Principio Business Park. This reduction in vehicle miles traveled represents less future wear and tear on

⁹ The number of injuries exceeds the number of accident events because there are more than 1.5 injuries, on average, per accident events classified as an accident with injury.



existing roads such as US 40, MD 222 and MD 272 and therefore is estimated as pavement maintenance cost savings. However, the construction of the Proposed Interchange at Belvidere Road and I-95 means that operation and maintenance costs will have to be incurred for this new infrastructure, thus representing a disbenefit of the project.

7.2.1 METHODOLOGY

The pavement maintenance cost reduction for existing roads is estimated based on the reduced number of vehicle miles traveled generated by the project. The reduced number of vehicle miles traveled is calculated separately for cars and trucks by combining the number of trips that would be re-routed to the Proposed Interchange in the Build case with the average trip length reduction for those trips that re-route due to the project. The number of trips that would be re-routed in the Build case is identified in the traffic demand estimates and the average trip length reduction for those trips is 1.1 mile per trip. The resulting reductions in car and truck vehicle miles traveled are transformed into the pavement maintenance cost reduction benefit using the appropriate monetary value of pavement cost savings per mile listed in the USDOT BCA Guidance. These benefits are discounted using an annual 7 percent discount rate.

The increased operation and maintenance costs for the Proposed Interchange is estimated from the 10-year maintenance cost data provided by KCI, assuming a linear expenditure pattern to estimate annual maintenance costs. These disbenefits are discounted using an annual 7 percent discount rate.

7.2.2 ASSUMPTIONS

The assumptions used in the estimation of pavement maintenance cost reduction and increased operation and maintenance costs benefits are summarized in the table below.

Table 9: Assumptions Used in the Estimation of Pavement Maintenance Cost Reduction and Increased Operation and Maintenance Costs Benefits

Variable Name	Unit	Value	Source
Number of miles reduced per trip due to Proposed Interchange	Miles	1.1	The Traffic Group
Pavement Cost Savings (cars)	\$ per vehicle mile	\$0	USDOT BCA Guidance for BUILD Projects
Pavement Cost Savings (trucks)	\$ per vehicle mile	\$0.10	USDOT BCA Guidance for BUILD Projects (1/3 60 kip 4-axle S.U. Truck/Rural Interstate; 1/3 60 kip 5-axle Combo Truck/Rural Interstate; 1/3 80 kip 5-axle Combo Truck/Rural Interstate)

7.2.3 BENEFIT ESTIMATES

The shorter route between I-95 and the Principio Business Park represents a reduction of more than 109 million vehicle miles traveled for cars and a reduction of more than 45 million vehicle miles traveled for trucks. The reduction in vehicle miles traveled represents less pavement



maintenance for existing roads such as US 40, MD 222 and MD 272, amounting to \$4.5 million (undiscounted) over the analysis period.

Similarly, the construction of the Proposed Interchange creates additional operation and maintenance costs in the amount of \$14.3 million (undiscounted) over the 20 years of analysis.

Table 10: Estimates of Pavement Maintenance Cost Reduction and Increased Operation and Maintenance Costs Benefits, Millions of 2017 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Pavement Maintenance Cost Reduction (for existing roads)	\$4.54	\$1.49
(-) Increased operation and maintenance costs (for the Proposed Interchange)	\$14.30	\$5.40

7.3 Economic Competitiveness

The proposed project would contribute to enhancing the economic competitiveness of the Nation through improvements in the mobility of people and goods within and across the study area. In this analysis, two measures of mobility are presented: travel-time savings and out-of-pocket vehicle operating cost savings.

In the Build scenario, the project would cause Principio-Business-Park-related traffic heading to or coming from I-95 to re-route to the Proposed Interchange and away from either MD 222 and US 40 or MD 272 and US 40. This represents a reduction in trip length, on average, of 1.1 miles per trip. The reduction in vehicle miles traveled translates directly into out-of-pocket vehicle operating costs savings for both cars and trucks. This reduction in vehicle miles traveled also represents travel time savings for Principio-Business-Park-related traffic. The fact that in the Build scenario a significant amount of traffic will avoid driving on US 40, an already congested road, produces additional travel time savings benefits above and beyond those captured by the reduced trip length. In particular, the fast growth of the Principio-Business-Park means that future congestion along US 40, MD 222 and MD 272 under the No Build scenario will be severe, thus making the re-routing of Principio-Business-Park traffic away from these roads beneficial to non-Principio-Business-Park-related traffic.

7.3.1 METHODOLOGY

Travel time savings are calculated for two types of trips occurring in the project area: 1) non-Principio-Business-Park-related trips, and 2) Principio-Business-Park-related trips. This BCA monetizes the travel time savings occurring only during peak hours, and therefore represents a conservative estimate of travel time savings benefits.

The differences in delays (in terms of seconds per vehicle) for AM peak and PM peak conditions under the Build and No Build scenarios were estimated using VISSIM micro-simulations for all relevant road segments in the project area (US 40, MD 222, MD 272 and I-95 between MD 222 and MD 272). In the case of Belvidere Road, delays for AM peak and PM peak under the Build scenario were estimated by The Traffic Group for the year 2017 assuming that the Proposed

Interchange is operational and those delays are assumed to grow at the same rate as delays for the other road projects in the project area (i.e., US 40, MD 222 and MD 272) under that same scenario.

The number of trips for non-Principio-Business-Park-related trips during peak hours was estimated separately for cars and trucks using the traffic demand estimates and the share of traffic that circulates during peak hours. The estimated number of hours of delay during peak hours was calculated for cars and trucks separately under the No Build and Build scenarios for each year of analysis. To do this, information on the number of peak hour trips per route (from the traffic demand estimates)¹⁰ and peak hour delays during the Build and No Build scenarios for those routes were combined. The difference between the annual peak hours of delays under the No Build and Build scenarios for cars and trucks constitutes the estimated annual travel time savings for non-Principio-Business-Park-related trips.

Similarly, the number of trips for Principio-Business-Park-related trips during peak hours was estimated separately for cars and trucks using the traffic demand estimates and the share of traffic that circulates during peak hours. The estimated number of peak hours of delay was calculated for cars and trucks separately under the No Build and Build scenarios for each year of analysis. However, to do this the routing of those trips taken during peak hours in the No Build scenario (from the traffic demand estimates) was combined with the peak delays under No Build scenario conditions to estimate annual hours of delay during peak hours in the No Build scenario. In the case of the Build scenario, the number of trips observed during peak hours on the different routes (including the new route using the Proposed Interchange) was combined with the delays observed at peak hours on those same routes under the Build conditions to estimate annual delay during peak hours in the Build scenario. The difference between the annual hours of delays during peak hours under the No Build and Build scenarios for cars and trucks constitutes the estimated annual travel time savings for Principio-Business-Park-related trips.

Finally, the peak-hour number of hours of delay savings for cars and trucks attributable to the project were monetized using the corresponding vehicle occupancy and value of time for cars and trucks, and discounted over the period of analysis using a 7 percent annual discount rate.

Out-of-pocket vehicle operating cost savings are estimated for Principio-Business-Park-related trips only (both cars and trucks). The number of annual Principio-Business-Park-related trips and their routing were identified in the traffic demand estimates by vehicle type and later combined with a reduction of 1.1 miles (on average) on trip length to arrive to the total number of vehicle miles of travel reduced for cars and trucks (separately). The reduction in vehicle miles traveled for cars and trucks were then combined with the per-mile value of vehicle operating cost reductions for each vehicle type and discounted using a 7 percent discount rate to monetize these benefits.

7.3.2 ASSUMPTIONS

The assumptions used in the estimation of travel time savings and out-of-pocket travel cost savings are summarized in Table 11 and Table 12 respectively.

¹⁰ Notice that non-Principio-Business-Park-related traffic does not change routing due to the project improvements.



Table 11: Assumptions Used in the Estimation of Travel Time Savings

Variable Name	Unit	Value	Source
NO BUILD SCENARIO			
Delays at US-40 (EB & WB), AM, 2017	Minutes / vehicle	2.36	The Traffic Group
Delays at MD-222 (NB & SB), AM, 2017	Minutes / vehicle	1.68	The Traffic Group
Delays at MD-272 (NB & SB), AM, 2017	Minutes / vehicle	0.94	The Traffic Group
Delays at Belvidere Rd. (NB & SB), AM, 2017	Minutes / vehicle	0.00	The Traffic Group
Delays at US-40 (EB & WB), PM, 2017	Minutes / vehicle	2.73	The Traffic Group
Delays at MD-222 (NB & SB), PM, 2017	Minutes / vehicle	2.14	The Traffic Group
Delays at MD-272 (NB & SB), PM, 2017	Minutes / vehicle	1.25	The Traffic Group
Delays at Belvidere Rd. (NB & SB), PM, 2017	Minutes / vehicle	0.00	The Traffic Group
Delays at US-40 (EB & WB), AM, 2040	Minutes / vehicle	5.11	The Traffic Group
Delays at MD-222 (NB & SB), AM, 2040	Minutes / vehicle	14.93	The Traffic Group
Delays at MD-272 (NB & SB), AM, 2040	Minutes / vehicle	9.26	The Traffic Group
Delays at Belvidere Rd. (NB & SB), AM, 2040	Minutes / vehicle	0.00	The Traffic Group
Delays at US-40 (EB & WB), PM, 2040	Minutes / vehicle	20.68	The Traffic Group
Delays at MD-222 (NB & SB), PM, 2040	Minutes / vehicle	9.67	The Traffic Group
Delays at MD-272 (NB & SB), PM, 2040	Minutes / vehicle	5.15	The Traffic Group
Delays at Belvidere Rd. (NB & SB), PM, 2040	Minutes / vehicle	0.00	The Traffic Group
BUILD SCENARIO			
Delays at US-40 (EB & WB), AM, 2017	Minutes / vehicle	2.36	The Traffic Group
Delays at MD-222 (NB & SB), AM, 2017	Minutes / vehicle	1.68	The Traffic Group
Delays at MD-272 (NB & SB), AM, 2017	Minutes / vehicle	0.94	The Traffic Group
Delays at Belvidere Rd. (NB & SB), AM, 2017	Minutes / vehicle	0.39	The Traffic Group
Delays at US-40 (EB & WB), PM, 2017	Minutes / vehicle	2.73	The Traffic Group
Delays at MD-222 (NB & SB), PM, 2017	Minutes / vehicle	2.14	The Traffic Group
Delays at MD-272 (NB & SB), PM, 2017	Minutes / vehicle	1.25	The Traffic Group
Delays at Belvidere Rd. (NB & SB), PM, 2017	Minutes / vehicle	0.43	The Traffic Group



Variable Name	Unit	Value	Source
Delays at US-40 (EB & WB), AM, 2040	Minutes / vehicle	3.84	The Traffic Group
Delays at MD-222 (NB & SB), AM, 2040	Minutes / vehicle	2.39	The Traffic Group
Delays at MD-272 (NB & SB), AM, 2040	Minutes / vehicle	1.47	The Traffic Group
Delays at Belvidere Rd. (NB & SB), AM, 2040	Minutes / vehicle	3.10	The Traffic Group
Delays at I-95 (between 222 & 272), AM 2040 (difference between No Build and Build)	Minutes / vehicle	0.00	The Traffic Group
Delays at US-40 (EB & WB), PM, 2040	Minutes / vehicle	4.74	The Traffic Group
Delays at MD-222 (NB & SB), PM, 2040	Minutes / vehicle	2.49	The Traffic Group
Delays at MD-272 (NB & SB), PM, 2040	Minutes / vehicle	3.16	The Traffic Group
Delays at Belvidere Rd. (NB & SB), PM, 2040	Minutes / vehicle	4.70	The Traffic Group
Delays at I-95 (between 222 & 272), PM 2040 (difference between No Build and Build)	Minutes / vehicle	0.02	The Traffic Group
OTHER VARIABLES			
AM Traffic in Project Area (cars)	Percentage	5.6%	The Traffic Group
AM Traffic in Project Area (trucks)	Percentage	5.6%	The Traffic Group
PM Traffic in Project Area (cars)	Percentage	6.1%	The Traffic Group
PM Traffic in Project Area (trucks)	Percentage	6.1%	The Traffic Group
Vehicle Occupancy, cars	persons/car	1.39	USDOT BCA Guidance for BUILD Projects
Vehicle Occupancy, trucks	persons/truck	1	USDOT BCA Guidance for BUILD Projects
Value of Time (car passengers) ¹¹	dollars/hour	\$14.20	USDOT BCA Guidance for BUILD Projects
Value of Time (truck passengers)	dollars/hour	\$28.60	USDOT BCA Guidance for BUILD Projects

Out-of-Pocket Vehicle Operating Costs are estimated using consumption rates for fuel, maintenance (including tires), and annual depreciation. Estimates of vehicle miles traveled and unit costs are applied to these consumption rates to calculate total out-of-pocket vehicle operating costs. The table below provides the unit cost estimates used in the analysis, along with the average reduction in trip length for Principio-Business-Park-related trips due to the Proposed Interchange.

¹¹ The value of time attributed to personal trips (\$14.20) is assumed for car passengers rather than the value of time attributed to all purposes (\$14.80) to be conservative.



Table 12: Assumptions Used in the Estimation of Out-of-Pocket Travel Cost Savings

Variable Name	Unit	Value	Source
Number of miles reduced per trip (applicable to Principio-Business-Park-related trips only)	Miles per trip	1.1	The Traffic Group
Vehicle Operating Cost Savings (cars)	dollars per mile	\$0.39	USDOT BCA Guidance
Vehicle Operating Cost Savings (trucks)	dollars per mile	\$0.90	USDOT BCA Guidance

7.3.3 BENEFIT ESTIMATES

By opening a direct connection between the Principio Business Park and I-95, the project generates more than 9.3 million hours of delay savings for cars and more than 2.5 million hours of delay savings for trucks realized by both users and non-users of the Principio Business Park. In addition, the shorter route represents a reduction in Principio-Business-Park-related trips of more than 109 million vehicle miles traveled for cars and a reduction of more than 45 million vehicle miles traveled for trucks. The reduction in vehicle miles traveled represents less fuel, maintenance and other operating costs for vehicle owners.

The monetized benefits for travel time savings and out-of-pocket vehicle operating costs are presented below.

Table 13: Estimates of Economic Competitiveness Benefits, Millions of 2017 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Travel Time Savings	\$163.91	\$51.88
Out-of-Pocket Vehicle Operating Cost Savings	\$83.54	\$27.43

7.4 Environmental Protection

The proposed project would contribute to environmental protection through a reduction in the emission of pollutants such as CO₂, CO, NO_x, PM₁₀, PM_{2.5}, SO₂ and Vehicle Organic Compounds (VOC). The reduction stems from two different characteristics of the Build scenario: first, the reduction on the number of vehicle miles traveled for Principio-Business-Park-related trips creates an immediate reduction in the amount of pollutants released to the atmosphere; second, the reduced congestion (and thus improved speeds) on roads used by non-Principio-Business-Park-related trips creates a reduction in the rate of emissions that also translates in a reduction in the amount of pollutants released to the atmosphere. The combination of these two effects is considered the emission cost savings benefits.

7.4.1 METHODOLOGY

The first step in the estimation of the emission cost savings benefits consists of identifying the emission rates under both the Build and No Build scenarios for both cars and trucks. This was done through running the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES), version MOVES2014a, software for a representative county in the U.S. and collecting the emission rates for all relevant pollutants (CO₂, CO, NO_x, PM₁₀, PM_{2.5}, SO₂ and VOC) for different speed bins (5 mile increments), different years (2016, 2025, 2035 and 2045) and different vehicle types (cars and trucks).¹² The emission rates were linearly interpolated for those years between the years reported in MOVES. The average speed of traffic in the project area under the Build and No Build scenarios was estimated using information on delays and the appropriate speed bin was used to identify the corresponding emission rates to be used in each scenario.

In the case of trips that re-route as a result of the project improvements (i.e., Principio-Business-Park-related trips), the reduction in vehicle miles traveled generates direct benefits by eliminating completely the emission of pollutants that would have occurred during the No Build scenario. As such, the annual emissions under the No Build scenario were calculated using the average speed for each corresponding year and the number of miles of travel that would be re-routed under the Build scenario. The resulting emissions were considered the emission cost savings for this traffic type and the value of emissions published by USDOT was then used to monetize these reductions.¹³

For trips that do not re-route as a result of the project improvements (i.e., non-Principio-Business-Park-related trips), the increased speeds mean that the No Build and Build scenarios have different emission rates for the same year and for the same pollutants. Using a trip length in the project area for trips that do not re-route of 5.8 miles per trip, the total annual emissions for each type of pollutant were estimated under the No Build and Build scenarios. The difference in annual emissions between the No Build and Build scenarios were considered the emission cost savings from this particular component and the value of emissions published by USDOT was then used to monetize these reductions.

The monetized value of the two components was added on an annual basis and discounted using a 7 percent annual discount rate to calculate the emission cost savings benefit.

7.4.2 ASSUMPTIONS

The assumptions used in the estimation of emission cost savings benefits are summarized in the table below.

¹² MOVES was run for Johnson County, Kansas (a representative county). For autos, the emissions correspond to those listed under Passenger Car; for trucks, they correspond to an average of the following categories: Combination long-haul truck, Combination short-haul truck, Single unit long-haul truck, and Single unit short-haul truck. The emission rates used in the analysis correspond to those listed under gasoline for passenger cars and diesel for trucks.

¹³ Following USDOT BCA Guidance, only reductions in VOC, NO_x, PM_{2.5} and SO₂ emissions were monetized as part of this BCA.



Table 14: Assumptions Used in the Estimation of Emission Cost Savings Benefits

Variable Name	Unit	Value	Source
Trip length in project area for vehicles not changing their route	Miles per trip	7.1	HDR estimate based on distance traveled on US 40 between MD 222 and MD 272
Social Cost of Carbon Monoxide (CO) emissions	\$ per METRIC ton	\$0	USDOT BCA Guidance for BUILD Projects
Social Cost of Volatile Organic Compounds (VOC) emissions	\$ per METRIC ton	\$2,100	USDOT BCA Guidance for BUILD Projects
Social Cost of Nitrogen Oxides (NO _x) emissions	\$ per METRIC ton	\$8,276	USDOT BCA Guidance for BUILD Projects
Social Cost of Fine Particulate Matter (PM _{2.5}) emissions	\$ per METRIC ton	\$378,580	USDOT BCA Guidance for BUILD Projects
Social Cost of Sulfur Dioxide (SO ₂) emissions	\$ per METRIC ton	\$48,913	USDOT BCA Guidance for BUILD Projects

7.4.3 BENEFIT ESTIMATES

The project is anticipated to reduce more than 291,000 metric tons of CO₂, more than 330 metric tons of CO, more than 200 metric tons of NO_x, more than 5 metric tons of PM₁₀, more than 5 metric tons of PM_{2.5}, more than 2 metric tons of SO₂ and more than 17 metric tons of VOC. However, following USDOT Guidance on BCAs, only the reductions in VOC, NO_x, PM_{2.5} and SO₂ emissions were monetized as part of this BCA, and the results are presented in the table below.

Table 15: Estimates of Emission Cost Savings Benefits, Millions of 2017 Dollars

	Over the Project Lifecycle	
	In Constant Dollars	Discounted at 7 Percent
Emission Cost Savings	\$3.77	\$1.18

7.5 Quality of Life

The project would contribute to enhancing quality of life in the study area through the reduction in truck traffic, leading to lower noise levels and an improved driving experience, and the attraction of more businesses, which is anticipated to generate economic development opportunities for the local community. In this rural area, the attraction of new businesses, the development of employment opportunities, and the provision of access to these jobs can improve the quality of life for Cecil County residents in several ways. The quality of life benefits were not monetized as part of this BCA.

7.6 Innovation

The project features three innovative characteristics: 1) the specific interchange design; 2) the project delivery method; and, 3) the financing sources. In order to take a conservative approach to the estimation of benefits, these characteristics were not formally included in the BCA analysis; however, they are described qualitatively below.

A Diverging Diamond Interchange (DDI) is one of the interchange options being proposed to meet the transportation needs of the area. This innovative interchange would be the first full DDI in Maryland. As documented in [FHWA's DDI Informational Guide¹⁴](#), DDIs have proven effective across the country. The safety benefits of a DDI are described in detail in the Safety section of the narrative, but the safety benefits estimated in this BCA do not assume that a DDI design will be used for the Proposed Interchange. The BCA assumes a regular interchange design to estimate benefits, and therefore the amounts reported for this benefit category are conservative.

Another innovative feature of this project is the use of Design-Build (DB) as a project delivery method. In this particular case, one entity – the design-build team – is anticipated to work under a single contract with the project owner to provide both design and construction services. The benefits of using a DB method for project delivery were not monetized as part of this BCA.

Finally, the project is using innovative financing by having project stakeholders Cecil County and/or SC provide all the planning, design, construction and right-of-way to complete this project. This innovative financing method was not analyzed quantitatively as part of the BCA.

7.7 Partnership

The project would contribute to enhancing public-private partnerships in the study area by bringing together three strong partners to achieve economic development goals in the rural parts of Cecil County, Maryland: Cecil County, Maryland Transportation Authority (MDOT MDTA) and Stewart Companies. This is a great example of a primarily local rural county teaming with a state transportation agency and the private sector to deliver a project that will increase job opportunities. The BCA did not monetize partnership benefits.

7.8 Non-Federal Revenue for Transportation Infrastructure Investment

The project would contribute to enhancing non-federal revenue for transportation infrastructure investment in the study area in two different ways: 1) increased toll revenues for heavy trucks; and 2) increased taxes for Cecil County. However, these benefits are not included as part of this BCA.

It is assumed that 40% to 50% of the heavy truck ADT would be heading northbound to Belvidere Road and would pay a US 40 or I-95 toll of \$60.00 (2018 dollars) and that 20% to 30% of cars heading northbound to Belvidere Road would pay a \$6.00 US 40 or I-95 toll. Daily toll revenues for heavy trucks would range between approximately \$189,600 and \$237,000 while car revenues would range between approximately \$22,800 and \$34,250. In addition, the project is expected to generate over \$18,800,000 of additional annual revenue for Cecil County in property taxes. Neither one of these benefits were quantified as part of the BCA.

¹⁴ FHWA, USDOT, "Diverging Diamond Interchange Informational Guide." 2014.
https://safety.fhwa.dot.gov/intersection/alter_design/pdf/fhwasa14067_ddi_infoguide.pdf (accessed July 13, 2018).



8. Summary of Findings and BCA Outcomes

The tables below summarize the BCA findings. Annual costs and benefits are computed over the lifecycle of the project (26 years). As stated earlier, construction is expected to be completed by 2022. Benefits accrue during the full operation of the project (2023 to 2042). **More detailed results (annual benefits by merit criteria) are presented in the BCA model spreadsheet.**

Table 16: Overall Results of the Benefit Cost Analysis, Millions of 2017 Dollars

Project Evaluation Metric	7% Discount Rate	3% Discount Rate
Total Discounted Benefits	\$83.18	\$155.89
Total Discounted Costs	\$44.82	\$49.72
Net Present Value	\$38.35	\$106.18
Benefit / Cost Ratio	1.9	3.1
Internal Rate of Return (%)	12.4%	
Payback Period (years)	7	

Considering all monetized benefits and costs, the estimated internal rate of return of the project is 12.4 percent. With a 7 percent real discount rate, the \$44.8 million capital investment would result in \$83.2 million in total benefits and a Benefit/Cost ratio of approximately 1.9. With a 3 percent real discount rate, the Net Present Value of the project would increase to \$106.2 million, for a Benefit/Cost ratio of 3.1.

Table 17: Benefit Estimates by Merit Criteria for the Full Build Alternative

Primary Selection Criteria	Benefit Categories	7% Discount Rate	3% Discount Rate
Safety	Accident Cost Reduction	\$6,598,767	\$12,137,549
State of Good Repair	Pavement Maintenance Cost Reduction	\$1,488,893	\$2,742,606
	(-) Increase in O&M Cost	-\$5,402,206	-\$9,178,518
Economic Competitiveness	Travel Time Savings	\$51,884,939	\$97,492,497
	Out-of-Pocket Vehicle Operating Cost Savings	\$27,427,061	\$50,468,799
Environmental Protection	Emission Cost Savings	\$1,177,743	\$2,231,372
Total Benefit Estimates		\$83,175,197	\$155,894,306

9. 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 I-95 at Belvidere Road Interchange using a 7 percent discount rate are summarized in the table below. The table provides the change in project NPV associated with variation in variables or parameters (listed in row), as indicated in the column headers.

For example, a 30 percent reduction in the value of time leads to a 40 percent reduction in the project NPV. A 20 percent increase in value of time raises the project NPV by 27 percent. The results of the sensitivity analysis show that the Benefit-Cost ratio is sensitive to changes in the assumed parameters and variables, however the net present value is consistently positive and the Benefit-Cost ratio is greater than one across the variations tested.

Table 18: Quantitative Assessment of Sensitivity, Summary

Parameter	Change in Parameter Value	New NPV, \$ Millions	Change in NPV, \$ Millions	New B/C Ratio
Value of Travel Time	Lower Bound of Range Recommended by US DOT (30% reduction in VOT) ¹⁵	\$22.79	-\$15.57	1.5
	Upper Bound of Range Recommended by US DOT (20% increase in VOT) ¹⁶	\$48.73	\$10.38	2.1
Value of Statistical Life	Lower Bound of Range Recommended by US DOT (\$5.2 million)	\$36.82	-\$1.53	1.8
	Upper Bound of Range Recommended by US DOT (\$12.9 million)	\$39.50	\$1.15	1.9
Capital Cost Estimate	25% Reduction (\$40.4 million)	\$49.56	\$11.21	2.5
	25% Increase (\$67.4 million)	\$27.15	-\$11.21	1.5
Annual O&M Cost Estimate	25% Reduction (\$0.5 million)	\$39.70	\$1.35	1.9
	25% Increase (\$0.9 million)	\$37.00	-\$1.35	1.8

¹⁵ A 30 percent reduction in value of time amounts to \$9.94 per hour for car passengers and \$20.02 per hour for truck passengers.

¹⁶ A 20 percent increase in value of time amounts to \$17.04 per hour for car passengers and \$34.32 per hour for truck passengers.