Technical Memorandum: Benefit-Cost Analysis of the I-95 / I-87 Rural Corridor, Resiliency, and Innovative Technology Improvements Project

Date: March 4, 2019

Subject: Benefit-Cost Analysis for the I-95 / I-87 Rural Corridor, Resiliency, and Innovative Technology Improvements Project

Project Description

The *I-95 / I-87 Rural Corridor, Resiliency, and Innovative Technology Improvements* (hereafter called the "Project") is comprised of 1) improvements to U.S. 64, U.S. 264, (future I-87), 2) improvements to I-95, and 3) broadband installation along US 64 between Williamston and Whalebone. The I-95 part of the Project will upgrade a 27-mile segment of the facility into a state of good repair and up to current design standards, add capacity, and improve safety on this national artery in North Carolina. It will ensure connections between the Southeast, Mid-Atlantic, Northeast, military installations and international ports on the eastern seaboard are maintained and enhanced.

The U.S. 64/264 (future I-87) portion of the Project will include upgrades to segments of the corridor between Exit 430 in Rolesville and exit 515 in Williamston from highway to interstate standards. At-grade intersections will be converted to interchanges and the roadway will be reconstructed to the standards of a modern interstate, with wider shoulders and a 70 mph speed limit. The Project's completion will be a significant effort towards developing a major east-west facility to serve Eastern North Carolina. Future I-87 will serve as an evacuation route and is an important logistics corridor connecting Raleigh with CSX's Carolina Connector (CCX) in Rocky Mount and the Port of Norfolk in Virginia.

Fiber optic cable will be installed in the right-of-way along future I-87 and on US 64 from Williamston to Whalebone. It will traverse the length of future I-87 from Raleigh to the Virginia border via US 17. In the near-term, the fiber optic cable will be coupled with cell towers and intelligent transportation system (ITS) equipment to provide variable message signs along future I-87 and US 64 to Whalebone and allow the state to exchange access to the highway right-of-way for private telecommunications capacity to fill gaps in access to high-speed communications in rural Eastern North Carolina. Longer term, the availability of the fiber optic cable prepares for future use of connected and autonomous vehicles. In addition, the corridor between Williamston and Whalebone will have wind detection systems that allow NCDOT to monitor wind speeds and close bridges at the coast when winds are excessive, saving lives and property damage. The resilience features included in the Project will avoid detours when severe flooding closes I-95 or future I-87 for days at a time.

Each component of the Project has independent utility, but the greatest benefits are realized when the three investments are made together.

The Project includes the following elements:

<u>I-95</u>

- Widen I-95 to eight lanes from Exit 13 to Exit 80 (I-5987)
    - As part of the reconstruction, raise bridges and roadway to avoid overtopping in severe flooding events

    - Conduct 2D hydraulic modeling to support design of raised bridges and roadway
- Interchange improvements (I-5879)
- Install gages on bridges and culverts to monitor flooding
- Conduct stress testing along the corridor
- Operate FITRANS/Bridgewatch systems

<u>Future I-87</u>

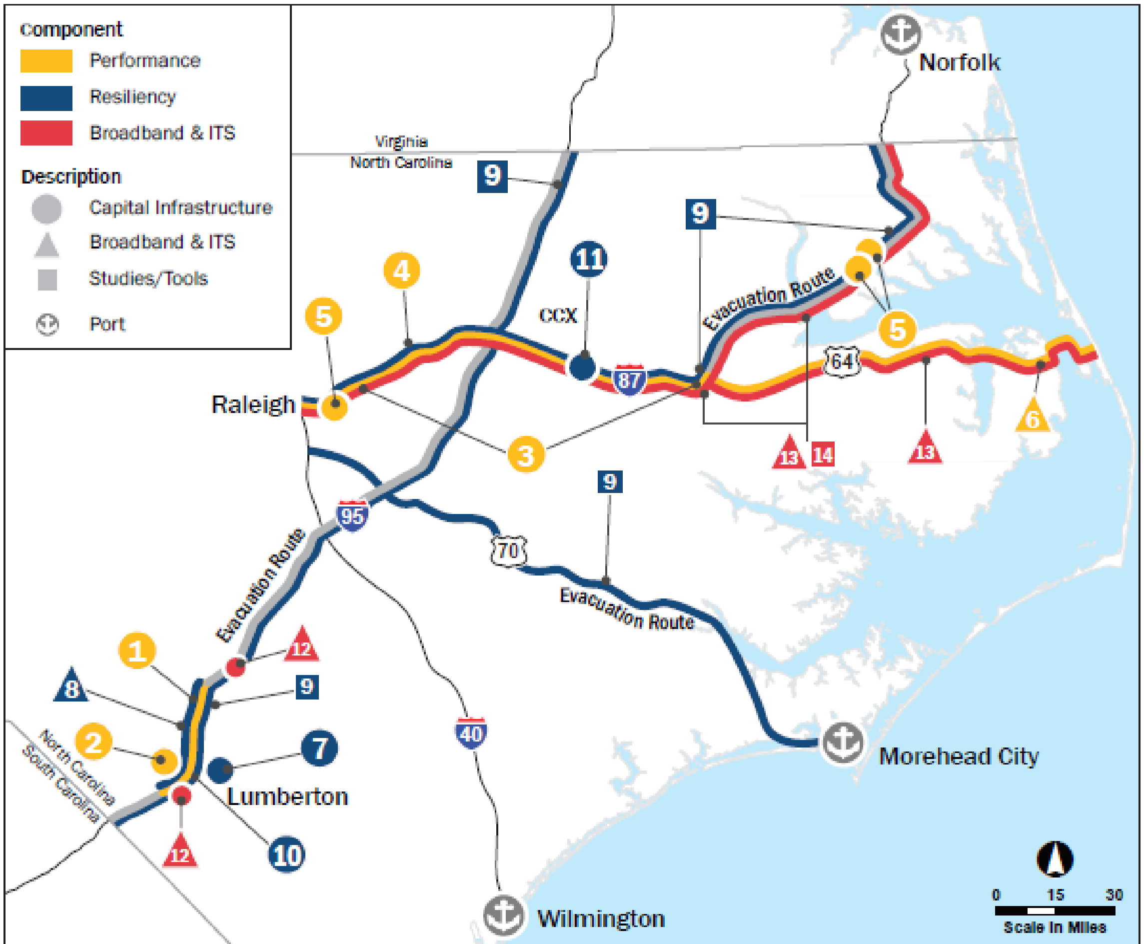
- Upgrade U.S. 70 to freeway standard from West Thurman Road/East Thurman Road interchange to the Havelock Bypass (R-5777C)
- Interchange improvements at Smithfield Road, Harvey Point Road/Wayne Fork Road, and New Hope Road (I-6007, R-5869A, R5869B)
- Widen US 264 from four to six lanes (I-6005)
- Upgrade to interstate standards on US 264 to Martin County line (H141265 and U-6149)
- Install ITS devices
- Install fiber along entire corridor
- Install gages on bridges and culverts to monitor flooding
- Conduct stress testing along the corridor
- Operate FITRANS/Bridgewatch systems
- Install rock plating along the roadway embankment near exit 487 on US 264 near Princeville to protect from flooding

<u>US 64 Williamston to Whalebone</u>

- Install fiber and ITS devices along the corridor

A map of the Project and the various elements is shown in Figure 1 followed by a matrix in Table 1 describing the project’s benefits.

Figure 1– Project Elements



Project Component	Link	Description
Performance (Capacity & Safety)	I-95	1 Expand to 8 lanes in St. Pauls and Lumberton areas between exits 13 and 40 2 Interchange project at exit 19 (Carthage Road)
	Future I-87 & Extensions	3 Upgrade to interstate standards from Zebulon to Williamston 4 Expand to 6 lanes in Zebulon area 5 Interchange projects at Smith Field Road, Harvey Point Road, and New Hope Road 6 Adding wind sign warnings along US 64 to the Outer Banks
Resiliency	I-95	7 Extending and raising two bridges crossing the Lumber River near exit 19 8 Add flood gauges for enhanced FITRANS performance from I-74 to Robeson/Cumberland County line 9 Implement stress test of interstate and primary routes (pursuing flood model partnership with Netherlands) along the interstate 10 Raise road elevation between exits 17-19 and 20-21
	Future I-87	9 Implement stress test of interstate and primary routes (pursuing flood model partnership with Netherlands) from I-440 to the Virginia line 11 Various spot projects to address road flooding in Princeville
	US 70 (Future I-42)	9 Implement stress test of interstate and primary routes (pursuing flood model partnership with Netherlands) from I-95 to Morehead City
Broadband & ITS	I-95	12 Install ITS devices on flood prone areas for rerouting along Lumber River and Cape Fear River crossings
	Future I-87 & Extensions	13 Install broadband along the interstate and US 64 14 Design an integrated corridor management system

Table 1 – Project Matrix

Current Status/Baseline & Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts	Affected Population	Economic Benefit (Net Present Values, $2017 M) Discounted at 7%	Page Reference in BCA
Future I-87 needs to be brought up to interstate standards in order to serve as an evacuation route and serve commerce as an important logistics corridor connecting Raleigh with CSX's Carolina Connector (CCX) in Rocky Mount and the Port of Norfolk in Virginia.	The future I-87 portion of the Project will include upgrades to segments of the corridor from highway to interstate standards. At-grade intersections will be converted to interchanges and the roadway will be reconstructed to the standards of a modern interstate, providing travel time savings, safety savings, and reducing detours during flooding events.	Safety:			
		Reduced Highway Fatalities and Crashes	Corridor drivers	$152.1	11
		Detour Safety Savings**	Auto and truck drivers who do not need to detour for flooding events	$31.2	12
		Wind Safety Savings	Corridor drivers	$18.4	18
		Economic Vitality:			
		Residual Value	NCDOT; Taxpayers	$46.3	18
I-95 near Lumberton experiences congestion and had extreme flooding during recent hurricanes, which causes delays and major detours for long periods of time.	The I-95 part of the Project will upgrade a 27-mile segment of the facility into a state of good repair and up to current design standards, add capacity, and improve safety.	Travel Time Savings	All auto and truck drivers on the national network	$2,110.7	19
		Truck Vehicle Operating Savings	Truck drivers on the national network	$551.4	20
		Fiber Benefits	Households on the future I-87 and US 64 corridors	$6.7	20
		Autonomous Vehicles Benefit (Average Scenario)	Auto and truck drivers on the future I-87 and US 64 corridors	$168.1	22
Much of eastern North Carolina lacks high speed internet access, and the US 64 corridor has experienced extreme wind events that have caused a fatality, injuries, and property damage.	Fiber optic cable will be installed along future I-87 and on US 64. The fiber will connect to ITS equipment to provide variable message signs. The availability of the fiber optic cable prepares for future use of autonomous vehicles. In addition, the corridor between Williamston and Whalebone will have real-time wind detection that will save lives and property damage.	Detour Travel Time Savings**	Auto and truck drivers who do not need to detour for flooding events	$53.3	23
		Detour Truck Operating Savings**	Truck drivers who do not need to detour for flooding events	$17.9	24
		Detour Value of Trips not Taken**	Drivers who do not need to choose between detouring or making a trip in a flooding event	$246.6	24
		Detour Vehicle Operating Cost Savings**	Auto drivers who do not need to detour for flooding events	$37.3	24

The corridors are susceptible to flooding and need resilience improvements to raise the roadway out of flood prone areas, protect the corridors from flooding, and monitor and plan for flooding events.	The resilience features included in the Project will avoid detours when severe flooding closes I-95 or future I-87 for days at a time, saving travel time, vehicle operating costs, safety savings, emissions, and truck operating costs.	Flood Resilience Repair Cost Savings	NCDOT; Taxpayers	$17.0	25
		Environmental			
		Emissions Savings (auto) [Includes diversions]	All residents and non-residents	$2.5	25
		Emissions Savings (truck) [Includes diversions]	All residents and non-residents	$17.5	25

Introduction

This technical memorandum estimates the long-term benefits associated with the Project. The long-term benefits presented relate to three goals identified in the INFRA 2019 Notice of Funding Opportunity (NOFO):[1] Safety, Economic Vitality, and Environmental. The results are the discounted streams of anticipated benefits and costs and the Benefit-Cost Ratios for the three individual Project components at 7 percent.[2]

The Project described in this application would support the region's economy over the long-term by providing the workforce and residents of North Carolina with improved interstate and freeway facilities, generating travel time savings, improving reliability through resilience, auto emissions reductions, reducing the likelihood for accidents, providing new fiber internet connections to rural counties, reducing the need to detour during flood events, improved safety during high wind events, flood resilience repair cost savings, and providing the infrastructure for autonomous vehicles.

The balance of this discussion describes the assumptions and methods used to develop the benefit-cost analysis and estimate the value of the long-term benefits generated by the investment. As directed in the INFRA guidance, the benefits of the capital investment have been estimated over a 30-year analysis horizon. The last element of the Project's construction would be completed in 2025, and an overall benefits period of 2026-2055 was used.

Benefits are estimated in accordance with guidance provided by U.S. Department of Transportation (U.S. DOT) for benefit-cost analysis. If no U.S. DOT guidance was available for the estimate, the Project team consulted industry research and Federal Emergency Management Agency (FEMA) guidance for the best practice and information on which to base the assumptions and methodology.

The benefits quantified in the benefit-cost analysis are described in the following pages in 2017 dollars discounted to 2019. Benefits for each Project element are described within the benefit categories.

Analysis Assumptions

A list of assumptions for the project is provided in the BCA workbook (see Inputs tab in the file NCDOT_I-95-I-87_INFRA_2019BCA.xls) as well as in Table 2.

Table 2- BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Rate	3%	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Year	2019	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs

[1] See INFRA 2019 Notice of Funding Opportunity, https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/buildamerica/259257/infra-2019-notice-funding-opportunity-fr.pdf

[2] The summary tables are displayed using both the required 7 percent discount rate, and a sensitivity analysis is presented using a 3 percent discount rate. The 3 percent discount rate is appropriate because elements of the project are related to improving the corridors' resilience and reduce maintenance and repairs, and as such have long useful lives that are more appropriately discounted at a lower rate than 7 percent.

Dollar Year	2017	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
I-87 Partial year 1 benefits (2026)	1.00	
I-87 Partial year 20 benefits (2046)	1.00	
I-95 Partial year 1 benefits (2027)	1.00	
I-95 Partial year 20 benefits (2047)	1.00	
Deflator	See "Deflator" Sheet	https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/hist10z1.xls
Auto Occupancy	1.68	2018 TIGER BCA Resource Guide, FHWA Statistics 2016, Table VM1
Annualization Factor for I-95	312	I-95 currently has 20 percent greater traffic volume on the weekends than typical weekdays, therefore it is appropriate to assume more than 5 days of traffic per week. This analysis uses 6 days of traffic per week.
Annualization Factor for I-87	280	
Share of typical AADT assumed to take the detour during closures	50%	
Estimated frequency of extreme wind events; one every 5 years	5	The fatality occurred under winds of 60kt and gusts of 70 kt (https://www.nhc.noaa.gov/data/tcr/AL092016_Hermine.pdf). Winds of 60 kt in the area were recorded in 2012 and 2016 per North Carolina Climate Office records; http://climate.ncsu.edu/climate/storm_reports?event=wind&reports=wind_reports&event_filter=&time=10yr&time_start=&time_end=&months_filter=&states=NC
50-year storm annual likelihood	2%	
Actual annual likelihood of the "500-year storm" like Florence. Note that Florence's intensity was considered a 500-year storm, but it's actual frequency is more often than that.	5%	Floyd (1999), Matthew (2016), and Florence (2018) can be considered 500-year storms that occurred within 20 years. Based on this history, conservatively assuming one storm of this caliber will occur every 20 years moving forward.
Factor for duration of a 50-year storm compared to Florence	1.5	
Lane Miles of I-95 in NC	1318.2	
Lane Miles of Future I-87 in NC	987.8	
Lane Miles of US 70 from I-40 to Morehead City	536	
Annual O&M Fiber (2017$)	$50,000	
Annual O&M ITS (2017$)	$100,000	
AADT Future I-87 (2017)	19,130	
Wake County	47,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Franklin County	24,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Nash County	36,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Edgecombe County	13,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Martin County	8,100	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Bertie County	13,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Chowan County	9,200	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Perquimans County	15,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Pasquotank County	13,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Camden County	13,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
AADT Future I-87 (2002)	13,710	

Wake County (2003)	36,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Franklin County (2003)	15,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Nash County	24,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Edgecombe County	9,100	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Martin County	7,500	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Bertie County	13,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Chowan County	7,500	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Perquimans County	12,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Pasquotank County (2003)	4,500	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Camden County	8,500	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
AADT annual growth Future I-87 (2002-2017)	2.2%	
AADT I-95 (2008)	38,500	
Exit 31-33	38,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Exit 22-25	37,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Exit 19-20	44,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Exit 14-17	35,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
AADT I-95 (2017)	52,750	
Exit 31-33	50,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Exit 22-25	52,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Exit 19-20	62,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Exit 14-17	47,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
AADT annual growth I-95 (2008-2017)	3.6%	NCDOT
Truck share I-95	22%	Statewide Travel Demand Model, February 2019
Truck share I-87	8%	Statewide Travel Demand Model, February 2019
AADT US 64 (2002)	9,089	
E of SR 1500	6,900	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of 64 Bus	6,900	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of SR 1342	14,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of SR 1241	7,300	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of SR 1229	2,600	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of SR 1229	2,700	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of US 264	3,400	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of NC 345	19,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of US 158	19,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
AADT US 64 (2017)	9,789	

E of SR 1500	7,600	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of 64 Bus	7,600	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of SR 1342	13,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of SR 1241	7,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of SR 1229	3,700	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of SR 1229	3,800	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of US 264	4,400	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
E of NC 345	20,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of US 158	21,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
AADT annual growth US 64 (2002-2017)	0.50%	NCDOT
Economic Vitality		
Value of Time All Purposes, 2017$	$16.10	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Value of Time Truck, 2017$	$28.60	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Truck operating savings per hour (2017$)	$42.70	Table 9 ATRI Operational Cost of Trucking 2018. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance. Excludes driver time (valued in travel time savings); http://atri-online.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf
Vehicle Operating Cost per mile (2017$), auto	$0.39	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Safety		
O- No injury (2017$)	$3,200	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
C - possible injury (2017$)	$63,900	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
B - non-incapacitating injury (2017$)	$125,000	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
A - incapacitating (2017$)	$459,100	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
K - killed (2017$)	$9,600,000	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
U - Injured (severity unknown) (2017$)	$174,000	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
# Accidents Reported (unknown if injured) (2017$)	$132,200	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Environmental		
VOC Value of Emissions (2017$) per short ton	$2,000	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
NOx Value of Emissions (2017$) per short ton	$8,300	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
PM Value of Emissions (2017$) per short ton	$377,800	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
SOx Value of Emissions (2017$) per short ton	$48,900	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Passenger Car Emission Rates per Mile, VOC, 2013-2024	0.6	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, Nox, 2013-2024	0.91	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, PM25, 2013-2024	0.01	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, CO2, 2013-2024	532	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, VOC, 2025-2034	0.27	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf

Passenger Car Emission Rates per Mile, Nox, 2025-2034	0.28	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, PM25, 2025-2034	0.01	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, CO2, 2025-2034	434	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, VOC, 2035-	0.21	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, Nox, 2035-	0.2	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, PM25, 2035-	0.01	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, CO2, 2035-	397	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Gasoline Consumption Per mile	0.04149	http://www.epa.gov/otaq/consumer/420f08024.pdf
Short tons per Metric Ton	1.1015	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
LDGV Emissions Rates g/hr VOC	2.683	nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT
LDGV Emissions Rates g/hr NOX	3.515	nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT
Truck Emissions Rate g per hour VOC (average of 8a and 8b trucks)	3.868	Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs
Truck Emissions Rate g per hour Nox (average of 8a and 8b trucks)	39.0515	Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs
Truck Emissions Rate g per hour PM2.5 (average of 8a and 8b trucks)	1.092	Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs
Truck Emissions Rate g per hour PM10 (average of 8a and 8b trucks)	1.187	Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs
Social Cost of Carbon		
	2017$ per metric ton	
2017	$1.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2020	$1.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2025	$1.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2030	$1.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2035	$2.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2040	$2.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2045	$2.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2050	$2.00	2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs

The analysis assumes that construction delays would result from 20 mph lower average speeds on future I-87 and I-95 for four years.

A key assumption to the analysis with regards to the detour benefits that result from the resilience projects is the frequency at which a flooding event occurs. The resilience projects would allow for better monitoring of flooding, as well as raising sections of roads and bridges to avoid flooding in the future on the I-95 corridor. Sections of I-95 near Lumberton experienced over a week of flooding during Hurricane Florence. Along the future I-87 corridor, the roadway will be protected from flooding in the Princeville area, which flooded during Hurricane Matthew.

Based on discussions with NCDOT resilience staff and reviewing historical cyclone event data that both affected and hit North Carolina directly,[3] a distinction was made between the typical "500-year storm" and the frequency at which the state is actually experiencing this type of storm. In the past 20 years, the state has been hit by three "500-year storms", including Floyd (1999), Matthew (2016), and Florence (2018). The 500-year storm denotes the likelihood of a storm of that caliber – the chance annually is one in 500 that a storm will hit. However, for this analysis, the actual frequency of the 500-year storms was used; in other words, because the state has had three in 20 years, a more conservative frequency of one in 20 was assumed moving forward. This is an appropriate assumption given that storms have intensified in scale and frequency in recent years and will likely continue due to the effects of climate change.

The risk of a one-in-20-year-storm is independent of a one-in-50-year-storm; as such the benefits of both storms are additive. Note that the analysis conservatively only quantifies benefits for the 20- and 50- year storms.

Benefits

Safety

There are multiple safety benefits expected from the Project. First, the Project elements will result in a safer facility with the upgrades reducing the number of crashes resulting in fatalities, injuries, and property damage. Second, the Project will eliminate the need for detours during flood events, saving vehicle miles traveled (VMT) and resulting in safety savings. Finally, the Project will add broadband over the US 64 corridor from Williamston to Whalebone, which will allow for wind speed monitoring and the avoidance of fatalities, injuries, and property damage from overturned vehicles from extreme wind events. The monetization of these safety benefits are described in this section.

The crash reduction factors were valued based on the KABCO score. KABCO refers to the letters used to designate five levels of crash severity used by police at a crash scene, and each type of injury has a different associated economic cost. Each fatal/injury crash avoided was valued at $132,000 for U – Injured (severity unknown), and $3,200 for O – No Injury (or PDO).

Reduced Highway Fatalities and Crashes

Future I-87

Based on crash reduction factors estimated by an AECOM safety analysis[4] that considers the current geometry of the facilities compared to the facilities with the Project, there are savings of 48 fatalities and injuries, and 79 property damage only (PDO) crashes avoided per year. These safety reduction factors were held constant throughout the analysis period and conservatively assume one person is involved in each crash. The distribution of expected injury types is important because each type of injury has a different associated economic cost (Table 3).

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[3] See "Storms That Have Directly Hit or Affected North Carolina.xlsx" in the Supplemental Materials

[4] See "AECOM Safety Analysis.pdf" in the Supplemental Materials.

Table 3 – I-87 Crash Reduction Factors

	Annual Crash Reduction (Number of Crashes)		
Project	**Fatal/Injury**	**PDO**	**Total**
I-87			
I-6007	1.6	3	4.6
I-6005	21	48.8	69.8
H141265(a)	10	9	19
U-6149	10	13.3	23.3
H141265(b)	4.4	3	7.4
R-5869A	0.59	1.31	1.9
R-5869B	0.64	1.35	1.99

Source: AECOM safety analysis. For more information, see Supplemental Materials. Note: conservatively assumes one person per crash.

The total reduction in fatalities, injuries, and property damage is valued as $71.5 million, discounted at 7 percent.

I-95

Based on crash reduction factors estimated by AECOM safety analysis that considers the current geometry of the facilities compared to the facilities with the Project, there are savings of 56 fatalities and injuries, and 228 PDO crashes avoided per year. These safety reduction factors were held constant throughout the analysis period and conservatively assume one person is involved in each crash.

The crash reduction factors shown in Table 4 were valued based on the KABCO score.

Table 4 – I-95 Crash Reduction Factors

	Annual Crash Reduction (Number of Crashes)		
Project	**Fatal/Injury**	**PDO**	**Total**
I-95			
I-5987	25.4	114.7	140.1
I-5879	0.2	0.61	0.81
H129200-BB	16.4	60.5	76.9
H129200-BA	14.4	52.9	67.2

Source: AECOM safety analysis. For more information, see Supplemental Materials. Note: conservatively assumes one person per crash.

The total reduction in fatalities and crashes was valued as $80.6 million, discounted at 7 percent.

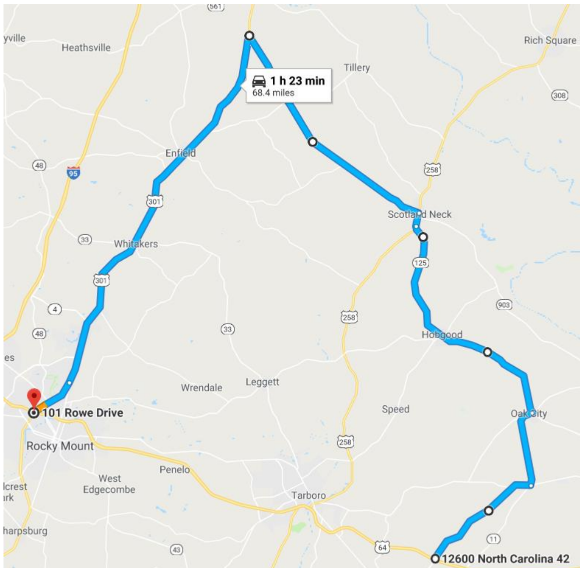
Detour Safety Savings

Future I-87

The Project will save VMT in the event of flooding in areas of the future I-87 corridor near Tarboro and Princeville. Drivers must detour around by a longer route, costing additional travel time and miles travelled. The Project will eliminate flooding in these low-lying areas and therefore VMT will be saved relative to the No Build. Shown in Figure 2 is one of the official detour routes (Route 4) used by vehicles to get around flooded sections of future I-87 during Hurricane Matthew in September 2016. A total of seven detour routes were issued by the NCDOT Traffic Systems

Operations Unit in the aftermath of Hurricane Matthew.[5] The route shown is an extra 42 miles and takes an additional hour to traverse. This detour lasted for half of a day. A summary of four of the seven detours is shown in Table 5. Note that there was no official detour issued for closures 1-3, so they are conservatively excluded from the analysis.

Figure 2 – Detour Route 4 around Tarboro and Princeville



Source: GoogleMaps

Table 5 – Future I-87 Detour Routes Additional Time and Mileage Net of No Build

	Route 4 WB Only	Route 5	Route 6	Route 7 WB Only
Hours	1.0	0.3	1.5	0.6
Miles	42.0	11.0	68.8	26.5
Days	0.5	5.0	2.3	1.7

Source: NCDOT Traffic Systems Operations Unit. Note that there was no official detour for Routes 1-3, so they are conservatively excluded from the analysis.

The volume of vehicles on this segment of future I-87 that were assumed to detour were estimated based on NCDOT traffic volumes for 2017. The VMT avoided by detours with the Project is shown in Table 6 .

[5] Please see the Supplemental Materials for descriptions of all seven detours.

Table 6 – Future I-87 Detour Vehicle Miles Travelled (VMT) and Vehicle Hours Travelled (VHT) Saved by the Project

Year	VMT	VHT
2026	3,669,033	83,799
2027	3,751,429	85,681
2028	3,835,676	87,605
2029	3,921,815	89,572
2030	4,009,888	91,584
2031	4,099,940	93,641
2032	4,192,013	95,744
2033	4,286,154	97,894
2034	4,382,409	100,092
2035	4,480,826	102,340
2036	4,581,454	104,638
2037	4,684,341	106,988
2038	4,789,538	109,391
2039	4,897,098	111,847
2040	5,007,073	114,359
2041	5,119,519	116,927
2042	5,234,489	119,553
2043	5,352,041	122,238
2044	5,472,234	124,983
2045	5,595,125	127,790
2046	5,720,776	130,660
2047	5,849,249	133,594
2048	5,980,608	136,594
2049	6,114,916	139,662
2050	6,252,240	142,798
2051	6,392,648	146,005
2052	6,536,210	149,284
2053	6,682,995	152,636
2054	6,833,077	156,064
2055	6,986,529	159,569

Note: these values were not adjusted for storm frequency

The rates of crashes that result in fatalities, injuries, and PDO are applied to the VMT avoided to derive the estimated crashes avoided from reduced VMT. The crash rates for fatalities and injured persons are found from the 2015 Crash Stats, and PDO are based on the share of fatal, injury, and PDO crashes over 2013-2015 that result in PDO from the same source. In total, 72 percent of crashes result in PDO; this share is held constant throughout the analysis period. These crash rates are shown in Table 7.

Table 7 - Crashes by Type per 100,000,000 VMT

	Rate per 100,000,000 VMT
Fatalities	1.15
Injured persons	79

Source: U.S. DOT, NHTSA Traffic Safety Facts 2016, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812554

These crash rates were used to estimate the number of crashes, injuries, and PDO that result from the diversion VMT and are valued using the KABCO scale.

The total annual value for crash severity is based on U.S. DOT guidance and the National Highway Safety Council estimates for the value of avoiding a crash. These estimates are applied to the number of crashes avoided to estimate the total value of crashes avoided from auto VMT avoided. Fatalities are valued at $9.6 million, injuries at $174,000, and PDO at $3,200.

The VMT and safety savings are factored by the share of traffic that may use the detour (50 percent assumed) and the probability of a similar hurricane event. In recent history, three Hurricane Matthew-type events have occurred in North Carolina over the last 20 years, including Floyd (1999), Matthew (2016), and Florence (2018). As a result, it is conservatively assumed that comparable future events will occur at the rate of one every 20 years. Because the risk of a one-in-20-year-storm is independent of a one-in-50-year-storm, the benefits of both storms are additive. The 50-year storm detours are assumed to be in place for 1.5 times longer than the 20-year detours.

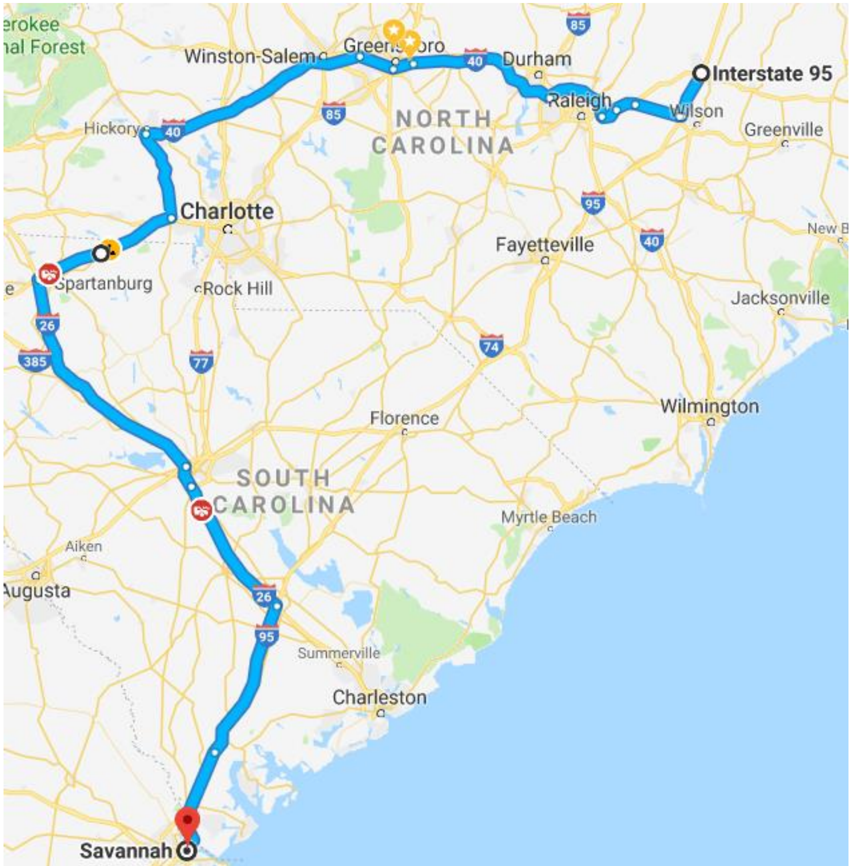
The total reduction in fatalities and crashes due to detour reductions results in a value of $0.8 million, discounted at 7 percent.

I-95

The Project will save VMT in the event of flooding in areas of the I-95 corridor near Lumberton. Drivers must detour around by a longer route, costing travel time and miles. The Project will eliminate flooding in these low-lying areas and therefore VMT will be saved relative to the No Build. Shown in Figure 3 is one of the official detour routes (Route 1) used by vehicles to get around flooded I-95 during Hurricane Florence in September 2018. A total of four detour routes were issued by the NCDOT Traffic Systems Operations Unit in the aftermath of Hurricane Florence.[6] The detour route shown is an extra 217 miles and takes an additional 3.3 hours to traverse. This detour lasted for seven days. A summary of the detours is shown in Table 9.

[6] Please see the Supplemental Materials for descriptions of all four detours.

Figure 3 – Detour Route 2 around Sections of I-95



Source: GoogleMaps

Table 8 – I-95 Detour Routes Additional Time and Mileage Net of No Build

	Route 1	Route 2	Route 3	Route 4
Hours	0.75	3.3	6.5	0.75
Miles	40	217	414	40
Days	0.13	5	2	2

Source: NCDOT Traffic Systems Operations Unit. Note: Routes 2 and 3 ran concurrently, Route 2 for 7 days and Route 3 for 2 days. To avoid double-counting, assumes 5 days of Route 2, and 2 days of Route 3.

The volume of vehicles on I-95 that were assumed to detour for northbound and southbound traffic in Savannah, Richmond, and Lumberton were averaged for 2017. The VMT avoided by detours with the Project is shown in Table 9.

Table 9 – I-95 Detour VMT and VHT Saved by the Project

Year	VMT	VHT
2026	123,425,849	1,937,141
2027	127,820,900	2,006,121
2028	132,372,454	2,077,556
2029	137,086,083	2,151,536
2030	141,967,559	2,228,149
2031	147,022,859	2,307,491
2032	152,258,172	2,389,658
2033	157,679,909	2,474,751
2034	163,294,707	2,562,874
2035	169,109,442	2,654,135
2036	175,131,233	2,748,646
2037	181,367,453	2,846,522
2038	187,825,737	2,947,883
2039	194,513,993	3,052,854
2040	201,440,411	3,161,563
2041	208,613,470	3,274,142
2042	216,041,953	3,390,731
2043	223,734,956	3,511,471
2044	231,701,898	3,636,510
2045	239,952,533	3,766,002
2046	248,496,964	3,900,105
2047	257,345,653	4,038,983
2048	266,509,432	4,182,806
2049	275,999,524	4,331,751
2050	285,827,546	4,486,000
2051	296,005,533	4,645,741
2052	306,545,946	4,811,171
2053	317,461,691	4,982,491
2054	328,766,133	5,159,912
2055	340,473,113	5,343,650

Note: these values were not adjusted for storm frequency

The rates of crashes that result in fatalities, injuries, and PDO are applied to the VMT avoided to derive the estimated crashes avoided from reduced VMT. The crash rates for fatalities and injured persons are from the 2015 Crash Stats, and PDO are based on the share of fatal, injury, and PDO crashes over 2013-2015 that result in PDO from the same source. In total, 72 percent of crashes result in PDO; this share is held constant throughout the analysis period. These crash rates are shown in Table 7.

These crash rates were used to estimate the number of crashes, injuries, and PDO that result from the diversion VMT and are valued using the KABCO scale. The total annual value for crash severity is based on U.S. DOT guidance and the National Highway Safety Council estimates for the value of avoiding a crash. These estimates are applied to the number of crashes avoided to estimate the total value of crashes avoided from auto VMT avoided. Fatalities are valued at $9.6 million, injuries at $174,000, and PDO at $3,200.

The VMT and safety savings are factored by the share of traffic that may use the detour (50 percent assumed) and the probability of a similar hurricane event. In recent history, three Hurricane Florence-type events have occurred in North Carolina over the last 20 years, including Floyd (1999), Matthew (2016), and Florence (2018). As a result, it is conservatively assumed that comparable future events will occur at the rate of one every 20 years. Because the risk of a one-in-20-year-storm is independent of a one-in-50-year-storm, the benefits of both storms are additive. The 50-year storm detours are assumed to be in place for 1.5 times longer than the 20-year detours.

The total reduction in fatalities and crashes due to detour reductions results in a value of $30.4 million, discounted at 7 percent.

Wind Safety Savings on US 64

The installation of broadband along US 64 from Williamston to Whalebone will enable real-time monitoring of wind speeds, allowing NCDOT to close bridges if winds reach certain thresholds. This will avoid fatalities, injuries, and property damage from extreme wind events.

Based on events in September 2016[7] under sustained winds of 60 knots (kt) and gusts of 70 kt, it is assumed that the Project would save one fatality, one non-serious injury, and two PDO crashes.[8] The frequency of an extreme wind event storm was estimated based on North Carolina Climate Office records[9] of winds reaching 60 kt in the area which occurred in 2012 and 2016, resulting in an extreme wind event once every five years.

Valuing the fatality at $9.6 million, the non-serious injury as B – non-incapacitating injury ($125,000), and the property damages at O – no injury ($3,200) and factoring for frequency results in a total wind safety savings of $18.4 million discounted at 7 percent.

Economic Vitality

Residual Value

Future I-87

Construction of the new roadway and interchanges would have residual value after the end of the 30-year analysis period, because the useful life of these elements is longer than 30 years. Highways and streets have a useful life of 60 years, and sewer systems (utilities) also have a useful life of 60 years,[10] while land does not depreciate. Assuming straight-line depreciation for all assets besides land, the value of land was added to the total value of the other assets and discounted from in the final year of the analysis period (2055). The residual value for the future I-87 portion of the Project discounted at 7 percent is $17.7 million.

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[7] Hampton, Jeff, The Virginian-Pilot, "One killed after tractor trailer overturns on Alligator River bridge from high winds," September 3, 2016https://pilotonline.com/news/local/article_b91e5f44-191c-5888-b402-b8a8ac2b2b8b.html

[8] National Hurricane Center Tropical Cyclone Report, Hurricane Hermine (AL092016), January 30, 2017, https://www.nhc.noaa.gov/data/tcr/AL092016_Hermine.pdf

[9] North Carolina Climate Office, Severe Storm Reports Tool, http://climate.ncsu.edu/climate/storm_reports?event=wind&reports=wind_reports&event_filter=&time=10yr&time_start=&time_end=&months_filter=&states=NC

[10] Bureau of Economic Analysis Rate of Depreciation, Service Lives, Declining-Balance Rates, and Hulten-Wykoff Categories, http://www.bea.gov/scb/account_articles/national/wlth2594/tableC.htm

I-95

Construction of the new roadway and interchanges would have residual value after the end of the 30-year analysis period, because the useful life of these elements is longer than 30 years. Highways and streets have a useful life of 60 years, and sewer systems (utilities) also have a useful life of 60 years,[11] while land does not depreciate. Assuming straight-line depreciation for all assets besides land, the value of land was added to the total value of the other assets and discounted from in the final analysis year (2055). The residual value for the I-95 portion of the Project discounted at 7 percent is $28.5 million.

Travel Time Savings

Future I-87

Based on the North Carolina Statewide Travel Demand Model (SWM), improvements to future I-87 would result in travel time savings for users. The model was run for four scenarios: 2025 No Build, 2025 Build, 2040 No Build, and 2040 Build. The results of the VHT for the national network were assessed, and the net change between the Build and No Build scenarios showed 3,135 daily hours saved in 2025 and 15,881 daily hours saved in 2040. The Build and No Build scenarios both grew at just under 2 percent per year between 2025 and 2040; this growth was assumed to continue to 2055 as well. The daily hours were annualized with a factor of 280.

Applying the truck share (8 percent) and the value of time for truckers ($28.60 per hour) results in the truck time savings. The remaining traffic was multiplied by the auto occupancy rate (1.68) and the value of auto time for all purposes ($16.10 per hour). The travel time savings on future I-87 amounts to $794.1 million discounted at 7 percent.

I-95

The I-95 travel time savings were estimated using a methodology that combined the North Carolina SWM with an analysis of existing and anticipated capacities along the project corridor. An analysis of the model's performance in the project corridor determined that the model was underestimating existing VHT. This was due to the model inaccurately reflecting the volume-delay relationships known to be occurring in the field today. As a result, a two-pronged approach was utilized. First, the model was run accounting for constrained capacity in the corridor by assigning the roadway as an arterial type in the No Build condition and upgrading to 8 lanes of interstate in the Build. This adjustment was required to compensate for way the model's volume-delay function was performing. Four scenarios were run similar to future I-87. The model results for the national network were adjusted to remove the I-95 corridor VHTs. The resulting VHTs represent delay throughout the network except for those experienced directly on the I-95 corridor.

In addition, a Model Verification Spreadsheet was used to better estimate and capture the greater volumes in the corridor than those that are reflected in the SWM results. This was done through a segment-by-segment assessment of traffic volumes, speeds, capacities, and diversions. Together, the I-95 VHT savings found from the spreadsheet model analysis were summed with the travel demand model non-I-95 network VHT savings to result in the total adjusted network VHT savings. In 2025, this totals 12,724 daily hours and increases to 20,665 daily hours in 2040. The result is a 3.3 percent growth rate applied to all interim years and extended to 2055. The daily hours were annualized by a factor of 312.[12]

Applying the truck share (22 percent) and the value of time for truckers results in the truck time savings. The remaining traffic was multiplied by the auto occupancy rate and the value of auto

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[11] Bureau of Economic Analysis Rate of Depreciation, Service Lives, Declining-Balance Rates, and Hulten-Wykoff Categories, http://www.bea.gov/scb/account_articles/national/wlth2594/tableC.htm

[12] I-95 currently has 20 percent greater traffic volume on the weekends than typical weekdays, therefore it is appropriate to assume more than 5 days of traffic per week. This analysis uses 6 days of traffic per week.

time for all purposes. The travel time savings on I-95 amounts to $1.3 billion discounted at 7 percent.

Delays During Construction

Construction delays are estimated for the future I-87 and I-95 corridors assuming a reduction in average travel speeds of 20 mph for the four years of construction.[13] The travel time loss is applied to all corridor drivers during the construction period and results in a cost of $3.8 million on future I-87 and $15.3 million on I-95. The delay cost is inclusive of the value of time and truck operating costs. No construction delays are anticipated on US 64.

Truck Vehicle Operating Savings

Future I-87

The travel time savings on future I-87results in operating cost savings for trucks. The operating cost per hour for trucks was found in the ATRI Operational Cost of Trucking,[14] which is inclusive of fuel, oil, truck/trailer lease, maintenance, driver benefits, tires, and insurance and totals $42.70 per hour. Driver time was excluded because it was already included in the Travel Time Savings benefit.

Multiplying the total travel time savings by the truck percentage (8 percent) and the truck operating cost per hour results in the truck operating savings. The total operating time savings for trucks on future I-87 amounts to $99.8 million discounted at 7 percent.

I-95

The travel time savings on I-95 results in operating cost savings for trucks and is estimated as described in the previous future I-87 section. Multiplying the total travel time savings by the truck percentage (22 percent) and the truck operating cost per hour results in the truck operating savings. The total operating time savings for trucks on future I-87 amounts to $451.6 million discounted at 7 percent.

Fiber Benefits

The Project utilizes transportation infrastructure investment to accomplish more than just transportation. There is a digital divide between rural and urban areas in terms of access to the high-speed broadband and communications capabilities needed to run modern applications. Figure 4 highlights the geographic pattern of high speed connectivity in the state and the large gaps in service in the Project area. This lack of access hinders economic development in small communities, limits agricultural access to applications that use big data to monitor and assess micro climate and yield data over large areas, and restricts educational opportunities. NCDOT will be working with its State Agency partners to utilize this new communications backbone to deliver these types of benefits to rural areas.

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[13] Assumes ROW and utilities do not result in construction delays.

[14] Table 9 ATRI Operational Cost of Trucking 2018. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance.

Figure 4 - Broadband Availability at 25 MBPS Download Speeds

Source: Connecting North Carolina, State Broadband Plan, 2016

The installation of fiber would allow for more accurate use of apps such as Waze and others that allow users to anticipate traffic conditions and plan ahead appropriately. The transportation system is therefore used more efficiently. In addition, emergency services, evacuation, public safety, and roadside safety can all be improved with better broadband connectivity.

Fiber is not installed along I-95 as part of this project because it will be installed as part of the 2017 NCDOT INFRA project.

Future I-87

The Project will install fiber along the entire future I-87 corridor, allowing for faster internet access for much of eastern North Carolina, among other connectivity improvements. This benefit is quantified using a willingness to pay (WTP) methodology. As found in the literature,[15] the value of an increase in broadband internet up to at least 4 megabytes per second (MBPS) is worth $10.37. This is assumed to be per household and is conservative because a typical internet speed is about 25 MBPS and therefore, would be valued higher. It is assumed that each household within the counties (estimated from Census 2010 data) along the future I-87 corridor outside of the urbanized areas[16] would be willing to pay once per year for the improved internet connection. The estimated county households decrease annually based on historical population growth from the NC Office of Budget and Management (OSBM).[17] The total fiber benefit for future I-87 amounts to $4.3 million discounted at 7 percent.

US 64

The Project will install fiber along the US 64 from Williamston to Whalebone, allowing for faster internet access for that area of eastern North Carolina, among other connectivity improvements. This benefit is quantified using a WTP methodology, as described for the previous future I-87 section. It is assumed that each household within the counties (estimated from Census 2010) along the US 64 corridor from Williamston to Whalebone would be willing to pay once per year for the improved internet connection. The estimated county households decrease annually based on historical population growth from the NC OSBM.[18] The total fiber benefit for the eastern segment of US 64 amounts to $2.4 million discounted at 7 percent.

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[15] Peterson, Richard, "Paying for Speed: Measuring Willingness to Pay in U.S. Broadband Markets," University of Colorado, October 17, 2017. See "WTP_Fiber.pdf" in the Supplemental Materials
[16] Excluded counties: Wake, Franklin, Nash, and Edgecombe
[17] NC Management and Budget, https://files.nc.gov/ncosbm/demog/countygrowth_cert_2016.html
[18] Ibid.

Autonomous Vehicles Benefit

The installation of fiber along the corridors would provide the groundwork for the future of autonomous vehicles. Fiber would be constructed by 2024 on the future I-87 and US 64 corridors. As smart vehicles are becoming more affordable, drivers will increasingly be driving autonomous vehicles. Preparing the transportation infrastructure for these new vehicle capabilities allows for the continued safe and efficient movement of goods and people along corridors.

This analysis considers a slow ramp-up of the use of autonomous vehicles on the corridors. Based on the paper “Autonomous Cars Self-Driving the New Auto Industry Paradigm,” by Morgan Stanley,[19] the costs and benefits of autonomous vehicles can be estimated for the corridor.

The paper estimates costs to drivers for vehicle upgrades to be about $10,000 in the near-term (assumed to be the first ten years of the benefits period) and $2,000 for the long-term (assumed for the following 20 years of the benefits period.) No costs for infrastructure or maintenance were assumed for the vehicles, but costs and maintenance were included in this analysis as part of the fiber installation. An adoption curve for the equipped-vehicles was assumed to be 14.5 percent in year 1 (2024) and increases to 90 percent by the end of the benefits period. The analysis therefore assumes that the region can attain all of the benefits of autonomous vehicles without 100 percent of the vehicles having autonomous capabilities.

To estimate the benefits, which include fuel savings, accident savings, productivity gains, and fuel and productivity savings from reduced congestion, the source estimated national benefits of $1.3 trillion in 2013 dollars, which are appropriately shared down to represent the Project areas. This analysis assumes a low scenario of realizing benefits, where autonomous vehicles and their associated benefits slowly “ramp up” in use in the corridor from 0 percent in year 1 (2024) to 72 percent by year 30 (2053).

A high benefits ramp-up scenario was also estimated, which assumes benefits accrue at 1 percent in 2024 and increase to 100 percent by 2046. To be conservative, the low scenario ramp-up was used in this analysis.

Future I-87

The costs to drivers of updating vehicles to autonomous features is estimated by assuming the approximate cost of $10,000 per vehicle, factored by AADT in the corridor annually, for the first ten years. Because each year an increasing proportion of vehicles are autonomous-equipped, the costs of the net new vehicles adopted are added. For the next 20 years, the net new vehicles are multiplied by the approximately $2,000 cost per vehicle.

Based on the AADT in the corridor in 2024 (about 22,300), the share of national benefits estimated for autonomous vehicles was shared down by a ratio of 22,300 vehicles compared to the national 250 million cars on the road. For future I-87, this represents 0.009 percent, or $123 million annually. This is held constant throughout the analysis period even though AADT increases. Multiplying the low scenario annual ramp-up of benefits by the annual benefit amount results in the total benefits per year.

Subtracting the total costs from the total benefit yields the net benefit of autonomous vehicles in the corridor. The total autonomous vehicle benefit for future I-87 amounts to $111.2 million discounted at 7 percent.

[19] "Autonomous Cars Self-Driving the New Auto Industry Paradigm", Morgan Stanley, November 6, 2013, pp48-52, http://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Nov2013MORGAN-STANLEY-BLUE-PAPER-AUTONOMOUS-CARS%EF%BC%9A-SELF-DRIVING-THE-NEW-AUTO-INDUSTRY-PARADIGM.pdf

US 64

The costs to drivers of updating vehicles to autonomous features is estimated by assuming the approximately $10,000 cost per vehicle, factored by AADT in the corridor annually, for the first ten years. Because each year an increasing proportion of vehicles are autonomous-equipped, the costs of the net new vehicles adopted are added. For the next 20 years, the net new vehicles are multiplied by the approximately $2,000 cost per vehicle.

Based on the AADT in the corridor in 2024 (about 10,100), the share of national benefits estimated for autonomous vehicles was shared down by a ratio of 10,100 vehicles compared to the national 250 million cars on the road. For US 64 this represents 0.004 percent, or $56 million annually. This is held constant throughout the analysis period even though AADT increases. Multiplying the low scenario annual ramp-up of benefits by the annual benefit amount results in the total benefits per year.

Subtracting the total costs from the total benefit yields the net benefit of autonomous vehicles in the corridor. The total autonomous vehicle benefit for future I-87 amounts to $56.9 million discounted at 7 percent.

Detour Travel Time Savings

Future I-87

The Project will save vehicles time in the event of flooding in low-lying areas of the future I-87 corridor. Drivers must currently detour around by a longer route, costing travel time and miles. The Project will eliminate flooding in these low-lying areas around Princeton and therefore travel time will be saved relative to the No Build. Shown in Figure 2 is one detour route used by vehicles to get around flooded sections of future I-87. The route shown is an extra 42 miles and takes an additional hour to traverse. This detour lasted for half of a day. A summary of four of the seven detours is shown in Table 5. Note that there was no official detour issued for closures 1-3, so they are conservatively excluded from the analysis.

Factoring the increased time by the number of vehicles, vehicle occupancy, and value of time as shown in Table 2 results in the avoided travel time for detoured autos and trucks. The travel time savings are factored by the share of traffic that may use the detour (50 percent assumed) and the probability of a similar hurricane event. Because the risk of a one-in-20-year-storm is independent of a one-in-50-year-storm, the benefits of both storms are additive. The 50-year storm detours are assumed to be in place for 1.5 times longer than the 20-year detours – a linear assumption.

The total travel time savings for detoured vehicles on future I-87 amounts to $1.9 million discounted at 7 percent.

I-95

The Project will save vehicles time in the event of flooding in low-lying areas of the I-95 corridor. Drivers must currently detour around by a longer route, costing travel time and miles. The Project will eliminate roadway flooding in these low-lying areas around Lumberton and therefore travel time will be saved relative to the No Build. Shown in Figure 3 is one detour route used by vehicles to get around flooded sections of I-95. The route shown is an extra 217 miles and takes an additional 3.3 hours to traverse. This detour lasted for seven days. A summary of the four detours is shown in Table 8.

The travel time savings for detoured vehicles on I-95 was calculated similar to the Future I-87. The total travel time savings for detoured vehicles on I-95 amounts to $51.4 million discounted at 7 percent.

Detour Truck Operating Savings

Future I-87

The travel time savings from the detours avoided on future I-87 results in operating cost savings for trucks. The operating cost per hour for trucks of $42.70 is based on the ATRI Operational Cost of Trucking,[20] which is inclusive of fuel, oil, truck/trailer lease, maintenance, tires, and insurance. Driver time was excluded as it is valued in the Detour Travel Time Savings benefit. Multiplying the total detour travel time savings by the truck percentage (8 percent) and the truck operating cost per hour results in the detour truck operating savings. The total operating time savings for detoured trucks on future I-87 amounts to $0.2 million discounted at 7 percent.

I-95

The travel time savings from the detours avoided on I-95 results in operating cost savings for trucks. The detour truck operating savings for I-95 were calculated similar to future I-87. The total operating time savings for detoured trucks on I-95 amounts to $17.6 million discounted at 7 percent.

Detour Value of Trips not Taken

There is value in trip-making; otherwise trips would not be made. Likewise, there is a cost to trips that are not taken, and the cost is primarily in productivity and economic activity. The value of a trip not taken is estimated using FEMA guidance, which assumes a 12-hour penalty for each one-way trip lost.[21] The analysis estimates the value of the loss in productivity and spending for each trip that is not made. The avoidance of this loss is a benefit for North Carolina.

Future I-87

When a trip is not made, the productivity and spending impacts associated with that trip are lost to the region. It is assumed that 50 percent of drivers will not make the trip under each detour scenario due to the added inconvenience. The value of trips not taken during future I-87 closures to traffic for the 20- and 50-year storms totals $34.1 million discounted at 7 percent.

I-95

Under Detour 2, I-95 in North Carolina is closed to northbound traffic, so northbound autos and trucks are assumed to not make the trip rather than diverting to other routes. In addition, 50 percent of all other detours are assumed to not make the trip due to the added inconvenience. The value of trips not taken due to closures and detours on I-95 for the 20- and 50-year storms totals $212.5 million discounted at 7 percent.

Detour Value of Vehicle Operating Cost Savings

Future I-87

Vehicle operating cost savings result from avoiding auto detours during flooding events in the corridors. Costs for auto trips are calculated as the out-of-pocket operating costs, which includes gas, maintenance, tires, and depreciation at $0.39 per mile in 2017 dollars based on USDOT guidance. The estimated auto VMT saved on the future I-87 corridor, factored for the frequency of a 20- and 50-year storm, and multiplied by the vehicle operating cost per mile totals $0.9 million discounted at 7 percent.

I-95

Vehicle operating cost savings result from avoiding auto detours during flooding events in the corridors were calculated for I-95 similar to future I-87. The estimated auto VMT saved on the I-95

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[20] Table 9 ATRI Operational Cost of Trucking 2018. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance.

[21] Federal Transit Administration, How to Use the FTA HMCE Tool, 2014, http://www.fta.dot.gov/documents/FTA-User_Guide-final.pdf

corridor, factored for the frequency of a 20- and 50-year storm, and multiplied by the vehicle operating cost per mile totals $36.4 million discounted at 7 percent.

Flood Resiliency Repair Cost Savings

Future I-87

The rock plating on the roadway embankment near exit 487 on US 264 (future I-87) near Princeville will keep that section of road from flooding, causing damage and detours for days in the area. The flooding in that section could cause an estimated $40 million in repairs if that segment were washed out. Factoring that cost by the annual likelihood of a storm at one in 20, results in an annual savings of $2 million. Discounted at 7 percent, the flood resiliency repair cost savings on future I-87 total $16.5 million.

I-95

The resiliency projects along I-95 include reconstructing and raising two bridges in Lumberton, and raising sections of the roadway north of Lumberton to avoid flooding in the future. NCDOT Division 6 provided an estimate of the repairs[22] to these sections of roadway after flooding caused damage during Hurricane Matthew. The estimate totaled $61,400 when factored by the assumed frequency of flooding events. In total, the I-95 resiliency repair cost savings result in $0.5 million when discounted at 7 percent.

Environmental

Auto Emissions Savings

Future I-87

Improvements to future I-87 would result in travel time savings for users and therefore reduced emissions. Annual volatile organic compounds (VOC) and nitrogen oxides (NOX) savings were estimated based on rates found from the EPA.[23] The tons of reduced emissions were monetized using the recommended value of emissions from INFRA 2019 guidance as shown in Table 2. The time savings from the travel demand model, as well as the diversions, were used to estimate emissions savings. In total, future I-87 results in auto emissions savings of $1.0 million, discounted at 7 percent.

I-95

Improvements to I-95 would result in travel time savings for users and therefore reduced emissions. Annual VOC and NOX savings were estimated based on rates found from the EPA.[24] The tons of reduced emissions were monetized using the recommended value of emissions from INFRA 2019 guidance as shown in Table 2. The time savings from the travel demand model, as well as the diversions, were used to estimate emissions savings. In total, I-95 results in auto emissions savings of $1.5 million, discounted at 7 percent.

Truck Emissions Savings

Future I-87

Based on the travel time savings, trucks also save time on future I-87 when the Project is operational. Based on emissions rates per idling hour as found in EPA guidance,[25] the tons of

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[22] See “I95 Damages.pdf” in the Supplemental Materials. The highlighted rows fall within the project area. Totals for Matthew were used in the analysis and assumed to be in 2017 dollars.

[23] EPA, Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks, EPA420=F-8-025, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT

[24] Ibid.

[25] EPA, Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks, EPA420=F-8-025, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT. Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs

VOC, NOX, particulate matter with a diameter less than 2.5 micrometers (PM2.5), and particulate matter with a diameter less than 10 micrometers (PM10) were estimated. The tons of reduced emissions were monetized using the recommended value of emissions from INFRA 2019 guidance as shown in Table 2. The time savings from the travel demand model, as well as the diversions, were used to estimate emissions savings. In total, truck emissions savings on future I-87 total $3.1 million, discounted at 7 percent.

I-95

Based on the travel time savings, trucks also save time on I-95 when the Project is operational. The emissions savings for I-95 were estimated similar to future I-87. In total, truck emissions savings on I-95 total $14.4 million, discounted at 7 percent.

Costs

Capital Costs

Future I-87

The capital costs for the future I-87 portion of the Project include the costs for the purchase of land, utilities, construction, resilience, soft costs, and contingency. The costs of the project elements are shown in Table 10.

Table 10 – Future I-87 Construction Costs, in 2019 dollars

STIP #	Project Build Cost (R, U, C, Res)	Right-of-Way Cost	Utilities Cost	Construction Cost	Resilience Cost
I-6007	$7,400,000	$1,700,000	$500,000	$5,200,000	$0
I-6005	$59,100,000	$4,900,000	$500,000	$53,700,000	$0
NA (Broadband)	$30,000,000	$0	$0	$30,000,000	$0
H141265	$87,000,000	$1,000,000	$1,000,000	$85,000,000	$0
U-6149	$112,100,000	$10,900,000	$2,500,000	$98,700,000	$0
H141265	$93,000,000	$1,000,000	$1,000,000	$90,000,000	$1,000,000
R-5869A	$36,900,000	$6,000,000	$900,000	$30,000,000	$0
R-5869B	$23,700,000	$3,400,000	$500,000	$19,800,000	$0

Source: NCDOT

The capital costs are applied over a five year construction period, beginning in 2021 and ending in 2025.

The resilience elements of the project include stress testing, adding gauges on bridges and culverts, and rock plating the roadway embankment near exit 487 on US 264 near Princeville. The resilience items total $1.4 million and will be constructed over three years from 2023-2025. Note that the capital costs for future I-87 also include the stress testing of the US 70 corridor from I-40 to Morehead City, and possibly other areas of the state.

Previously incurred costs for professional engineering (PE) are estimated at $896,613 in 2017 dollars, and were assumed to have been spent in 2018.

The capital costs were converted to 2017 dollars and discounted at 7 percent; the total capital costs for future I-87 are $331.9 million.

I-95

The capital costs for the I-95 portion of the Project include the costs for the purchase of land, utilities, construction, resilience, soft costs, and contingency. The costs of the project elements are shown in Table 11.

Table 11 – I-95 Construction Costs, in 2019 dollars

STIP #	Project Build Cost (R, U, C, Res)	Right-of-Way Cost	Utilities Cost	Construction Cost	Resilience Cost
I-5987	$446,750,000	$32,000,000	$1,000,000	$413,750,000	$0
I-5879	$12,939,000	$540,000	$0	$12,399,000	$0
H129200-BB	$110,700,000	$20,000,000	$600,000	$90,000,000	$100,000
H129200-BA	$184,800,000	$20,000,000	$600,000	$115,000,000	$49,200,000

Source: NCDOT

The capital costs are applied over a six year construction period, beginning in 2020 and ending in 2025.

The resilience elements of the project include raising bridges and roadway near Lumberton, adding gauges on bridges and culverts, and stress testing. The resilience items total $1.7 million and will be constructed over two years from 2023-2024.

Previously incurred costs for professional engineering (PE) are estimated at $896,613 in 2017 dollars, and were assumed to have been spent in 2018.

The capital costs were converted to 2017 dollars and discounted at 7 percent; the total capital costs for future I-87 are $555.3 million.

US 64

The capital costs for the US 64 portion of the Project include the costs for construction of broadband and ITS devices. The costs of the project elements are shown in Table 12.

Table 12 – US 64 Construction Costs, in 2019 dollars

STIP #	Project Build Cost (R, U, C, Res)	Right-of-Way Cost	Utilities Cost	Construction Cost	Resilience Cost
NA (Broadband)	$15,000,000	$0	$0	$15,000,000	$0

Source: NCDOT

The capital costs are applied over a two year construction period, beginning in 2022 and ending in 2023. The capital costs were converted to 2017 dollars and discounted at 7 percent; the total capital costs for US 64 are $11.5 million.

Operating and Maintenance Costs

Future I-87

The project requires annual and periodic operating and maintenance (O&M) costs to keep the roads and bridges in a state of good repair. Maintenance begins in 2026, as the first full year of operation, and the O&M costs are the incremental difference between the current O&M costs for the corridor compared to the costs to maintain the upgraded segments. The O&M includes Renewal & Replacement (R&R) costs.

ITS and fiber are assumed to require minimal maintenance annually, estimated at $100,000 and $50,000 per year, respectively. The FITRANS/Bridgewatch elements of the resilience projects require annual operating costs of $375,000.

The total O&M costs over the analysis period and discounted at 7 percent is $7.5 million.

I-95

The project requires annual and periodic O&M costs to keep the roads and bridges in a state of good repair. Maintenance begins in 2026, as the first full year of operation, and the O&M costs are the incremental difference between the current O&M costs for the corridor compared to the costs to maintain the upgraded segments. The O&M includes R&R costs.

ITS and fiber are assumed to require minimal maintenance annually, estimated at $100,000 and $50,000 per year, respectively. The FITRANS/Bridgewatch and gauges elements of the resilience projects require annual operating costs of $375,000 and $51,000 annually, respectively.

The total O&M costs over the analysis period and discounted at 7 percent is $12.1 million.

US 64

The ITS and fiber project elements require minimal maintenance annually, estimated at $100,000 and $50,000 per year, respectively. Maintenance begins in 2024, as the first full year of operation.

The total O&M costs over the analysis period and discounted at 7 percent is $1.4 million.

Summary

Table 13 summarizes the discounted value of the benefits and costs discussed in this memorandum for the total Project. Taken in total and using a 7 percent discount rate, the Project provides $3.4 billion dollars of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 3.82, a solid return on these critical investments. The net benefits total $2.5 billion.

In addition, each of the project elements – future I-87, I-95, and US 64 – also has greater benefits than costs. Future I-87 has net benefits of $814.0 million, I-95 has net benefits of $1,659.4 million, and US 64 has $64.9 million net benefits, resulting in BCRs of 3.45, 3.99, and 6.66 respectively. The BCA for each individual project element is shown in Table 14, Table 15, and Table 16.

The summary tables are displayed using both the required 7 percent discount rate, and an alternative 3 percent discount rate. The 3 percent discount rate is appropriate because elements of the project are related to improving the corridors' resilience and reducing maintenance and repairs, and as such have long useful lives that are more appropriately discounted at a lower rate than 7 percent.

Table 13 – Total Project Benefit-Cost Analysis (2020-2055 in 2017 $M)

	Total Project	
	Values stated in 2017 $M	
	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$898.7	$1,049.0
Total Costs	***$898.7***	***$1,049.0***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	$152.1	$93.9
Detour Safety Savings**	$31.2	$68.0
Wind Safety Savings	$18.4	$33.9
Sub-Total Safety Benefits	***$201.7***	***$195.8***
Economic Vitality		
Residual Value	$46.3	$182.3
Travel Time Savings	$2,110.7	$4,772.9
Delays During Construction	-$19.2	-$22.7
Truck Vehicle Operating Savings	$551.4	$1,219.8
Fiber Benefits	$6.7	$12.0
Autonomous Vehicles Benefit (Low Scenario)	$168.1	$546.9
Detour Travel Time Savings**	$53.3	$116.1
Detour Truck Operating Savings**	$17.9	$39.0
Detour Value of Trips not Taken**	$246.6	$535.7
Detour Vehicle Operating Cost Savings**	$37.3	$81.3
Flood Resilience Repair Cost Savings	$17.0	$33.8
Sub-Total Economic Vitality	***$3,236.2***	***$7,517.3***
Environmental		
Emissions Savings (auto) [Includes diversions**]	$2.5	$5.7
Emissions Savings (truck) [Includes diversions**]	$17.5	$38.7
Sub-Total Environmental	***$20.0***	***$44.4***
O&M Costs	-$21.0	-$41.7
Net O&M	***-$21.0***	***-$41.7***
Total Benefits	***$3,436.9***	***$7,715.8***
BC Ratio	**3.82**	**7.36**
Net Present value	**$2,538.2**	**$6,666.8**

**Note: Sum of 20-year and 50-year storms

Table 14 – Future I-87 Benefit-Cost Analysis (2021-2055 in 2017 $M)

	I-87 Upgrade to Interstate between Exits 432-515; Flood Resiliency; Broadband Installation	
	30 Year Benefits Period (2026-2055)	
	Values stated in 2017 $M	
	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$331.9	$386.9
Total Costs	***$331.9***	***$386.9***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	$71.5	$44.7
Detour Safety Savings**	$0.8	$1.6
Wind Safety Savings	NA	NA
Sub-Total Safety Benefits	***$72.3***	***$46.3***
Economic Vitality		
Residual Value	$17.7	$69.9
Travel Time Savings	$794.1	$1,920.4
Delays During Construction	-$3.8	-$4.5
Truck Vehicle Operating Savings	$99.8	$241.4
Fiber Benefits	$4.3	$7.8
Autonomous Vehicles Benefit (Low Scenario)	$111.2	$367.8
Detour Travel Time Savings**	$1.9	$4.0
Detour Truck Operating Savings**	$0.2	$0.5
Detour Value of Trips not Taken**	$34.1	$71.8
Detour Vehicle Operating Cost Savings**	$0.9	$2.0
Flood Resilience Repair Cost Savings	$16.5	$32.8
Sub-Total Economic Vitality	***$1,077.0***	***$2,713.8***
Environmental		
Emissions Savings (auto) [Includes diversions**]	$1.0	$2.5
Emissions Savings (truck) [Includes diversions**]	$3.1	$7.4
Sub-Total Environmental	***$4.1***	***$9.9***
O&M Costs	-$7.5	-$15.3
Net O&M	***-$7.5***	***-$15.3***
Total Benefits	***$1,145.9***	***$2,754.8***
BC Ratio	**3.45**	**7.12**
Net Present value	**$814.0**	**$2,368.0**

**Note: Sum of 20-year and 50-year storms

Table 15 – I-95 Project Benefit-Cost Analysis (2020-2055 in 2017 $M)

	I-95 Widen to 8 Lanes between Exits 13-40; Interchange improvements; Flood Resiliency	
	30 Year Benefits Period (2026-2055)	
	Values stated in 2017 $M	
	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$555.3	$649.1
Total Costs	***$555.3***	***$649.1***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	$80.6	$49.2
Detour Safety Savings**	$30.4	$66.4
Wind Safety Savings	NA	NA
Sub-Total Safety Benefits	***$111.0***	***$115.6***
Economic Vitality		
Residual Value	$28.5	$112.4
Travel Time Savings	$1,316.7	$2,852.6
Delays During Construction	-$15.3	-$18.2
Truck Vehicle Operating Savings	$451.6	$978.4
Fiber Benefits	NA	NA
Autonomous Vehicles Benefit (Low Scenario)	NA	NA
Detour Travel Time Savings**	$51.4	$112.1
Detour Truck Operating Savings**	$17.6	$38.5
Detour Value of Trips not Taken**	$212.5	$463.9
Detour Vehicle Operating Cost Savings**	$36.4	$79.4
Flood Resilience Repair Cost Savings	$0.5	$1.0
Sub-Total Economic Vitality	***$2,099.9***	***$4,620.1***
Environmental		
Emissions Savings (auto) [Includes diversions**]	$1.5	$3.2
Emissions Savings (truck) [Includes diversions**]	$14.4	$31.3
Sub-Total Environmental	***$15.9***	***$34.5***
O&M Costs	-$12.1	-$23.8
Net O&M	***-$12.1***	***-$23.8***
Total Benefits	***$2,214.7***	***$4,746.3***
BC Ratio	**3.99**	**7.31**
Net Present value	**$1,659.4**	**$4,097.3**

**Note: Sum of 20-year and 50-year storms

Table 16 – US 64 Project Benefit-Cost Analysis (2022-2053 in 2017 $M)

	Extend Broadband on US 64 to Whalebone 30 Year Benefits Period (2024-2053) Values stated in 2017 $M	
	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$11.5	$13.1
Total Costs	***$11.5***	***$13.1***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	NA	NA
Detour Safety Savings**	NA	NA
Wind Safety Savings	$18.4	$33.9
Sub-Total Safety Benefits	***$18.4***	***$33.9***
Economic Vitality		
Residual Value	NA	NA
Travel Time Savings	NA	NA
Delays During Construction	NA	NA
Truck Vehicle Operating Savings	NA	NA
Fiber Benefits	$2.4	$4.3
Autonomous Vehicles Benefit (Low Scenario)	$56.9	$179.1
Detour Travel Time Savings**	NA	NA
Detour Truck Operating Savings**	NA	NA
Detour Value of Trips not Taken**	NA	NA
Detour Vehicle Operating Cost Savings**	NA	NA
Flood Resilience Repair Cost Savings	NA	NA
Sub-Total Economic Vitality	***$59.3***	***$183.3***
Environmental		
Emissions Savings (auto) [Includes diversions**]	NA	NA
Emissions Savings (truck) [Includes diversions**]	NA	NA
Sub-Total Environmental	***$0.0***	***$0.0***
O&M Costs	-$1.4	-$2.6
Net O&M	***-$1.4***	***-$2.6***
Total Benefits	***$76.3***	***$214.6***
BC Ratio	**6.66**	**16.38**
Net Present value	**$64.9**	**$201.5**

**Note: Sum of 20-year and 50-year storms

List of Supporting Information

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AECOM Safety Analysis.pdf

AECOM Travel Demand Model Methodology.pdf

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Excel O&M Sources from NCDOT:

I-87 Maintenance Cost from Nc 58 to Thomas Road Overpass U-6149 limits, existing(002).xlsx

I-87 Maintenance Cost from Nc 58 to Thomas Road Overpass U-6149 limits, improved (002).xlsx

I-87 Maintenance Cost from Thomas Road Overpass to Williamston, improve (002).xlsx

I-87 Maintenance Cost from Thomas Road Overpass to Williamston, existing (002).xlsx

I-87 Maintenance Cost I-587 (US 264) to Nc 58 existing (002).xlsx

I-87 Maintenance Cost I-587 (US 264) to Nc 58 improved (002).xlsx

I-6005 I-87 Maintenance Cost from Wendell Blvd to US 264 existing (002).xlsx

I-6005 I-87 Maintenance Cost from Wendell Blvd to US 264 proposed (002).xlsx

I-87 R-5869A and R-5969B existing (002).xlsx

I-87 R-5869A and R-5969B improved (002).xlsx

I-95 Maintenance Cost I-95 Exit 13 to Exit 19 existing (002).xlsx

I-95 Maintenance Cost I-95 Exit 13 to Exit 19 Improve (002).xlsx

I-95 Maintenance Cost I-95 Exit 19 to Exit 22 Existing (002).xlsx

I-95 Maintenance Cost I-95 Exit 19 to Exit 22 improved (002).xlsx

I-95 Maintenance Cost I-95 Exit 22 to Exit 40 existing (002).xlsx

I-95 Maintenance Cost I-95 Exit 22 to Exit 40 improved (002).xlsx

NCDOT Division 6, I95 Damages.pdf

NCDOT Traffic Systems Operations Unit, Future I87 Matthew Detour List.docx

NCDOT Traffic Systems Operations Unit, I95 Florence Detour List.docx