Technical Memorandum: Benefit-Cost Analysis of the Future I-87 Resiliency, Innovative, Safety, Economic (RISE) Project

Date: February 24, 2020

Subject: Benefit-Cost Analysis for the Future I-87 Resiliency, Innovative, Safety, Economic (RISE) Project

Project Description

The *Future I-87 Resiliency, Innovative, Safety, Economic (RISE) Project* (hereafter called the "Project") is composed of 1) improvements to US 64 and US 17 (future I-87) and 2) broadband installation along US 64 between Williamston and Whalebone. The US 64/17 (future I-87) portion of the Project will include upgrades from highway to interstate standards for segments of the corridor from Raleigh to US 17 near Williamston. 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 the future I-87 corridor and on US 64 from Williamston to Whalebone. It will also traverse the length of the future I-87 corridor 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 the future I-87 corridor 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 resiliency features included in the Project will avoid detours when severe flooding may close the future I-87 corridor for days at a time.

The components of the Project have independent utility, but the greatest benefits are realized when the investments are made together.

The Project includes the following elements:

Future I-87

- Interchange improvements on US 64 at Smithfield Road (I-6007) and on US 17 at Harvey Point Road/Wayne Fork Road and New Hope Road (R-5869A, R5869B)
- Widen US 64 from four to six lanes (I-6005)
- Upgrade to interstate standards on US 64 to US 17 near Williamston (H141265, U-6149, and H171801)
- Install ITS devices
- Install fiber optic cable along entire corridor
- Install 36 gauges on bridges and culverts to monitor flooding
- Conduct vulnerability assessment and stress testing along the corridor
- Operate FIMANT/Bridgewatch systems

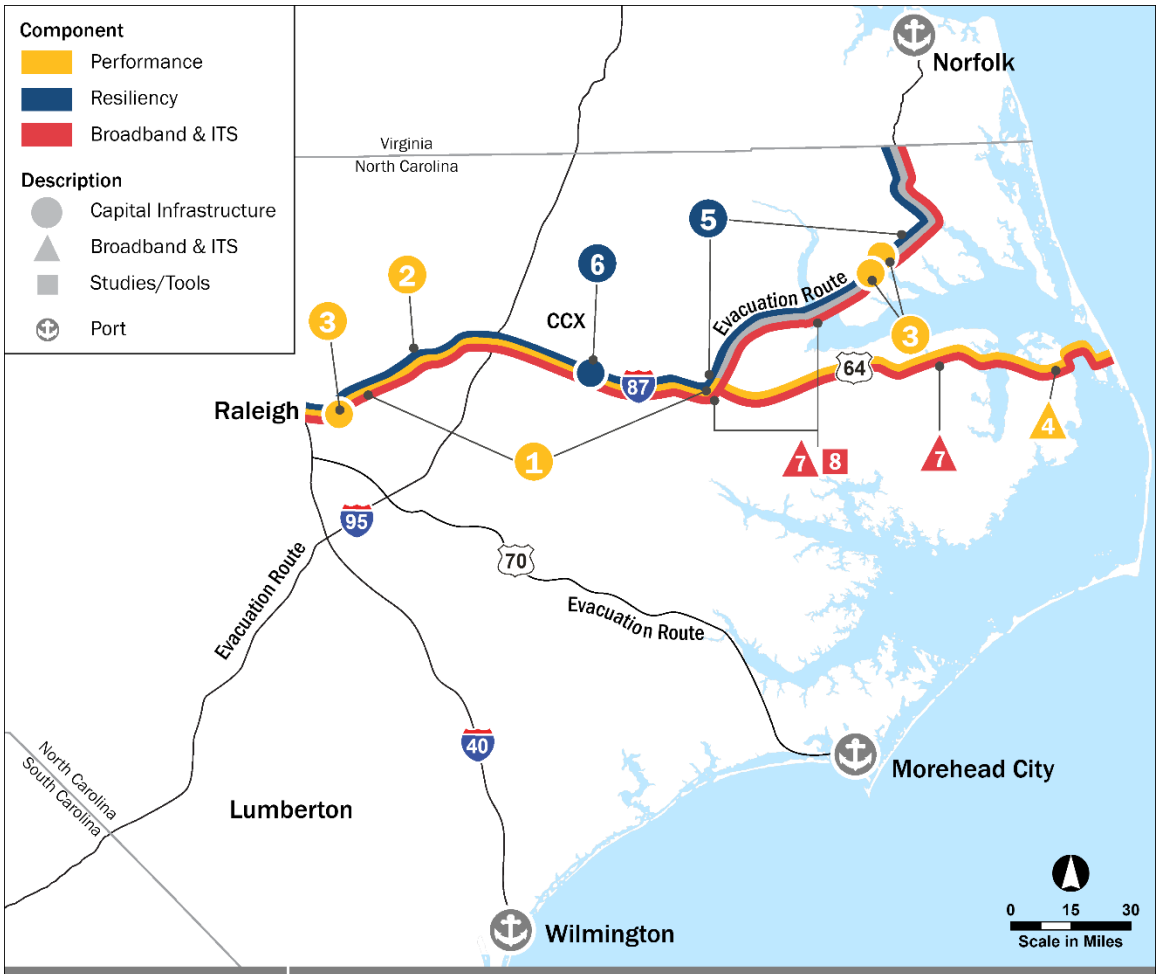
- Install rock plating along the roadway embankment near exit 487 on US 64 near Princeville to protect from flooding

US 64 Williamston to Whalebone

- Install fiber optic cable 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 benefits.

Figure 1– Project Elements



Project Component	Description
Performance (Capacity & Safety)	1 Upgrade to interstate standards from Zebulon to Williamston 2 Expand to 6 lanes in Zebulon area 3 Interchange projects at Smith Field Road, Harvey Point Road, and New Hope Road 4 Adding wind sign warnings along US 64 to the Outer Banks
Resiliency	5 Implement stress test of interstate and primary routes (pursuing flood model partnership with Netherlands) from I-440 to the Virginia line 6 Various spot projects to address road flooding in Princeville
Broadband & ITS	7 Install broadband along Future I-87 and US-64 8 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, $2018 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	$86.8	9
		Detour Safety Savings**	Auto and truck drivers who do not need to detour for flooding events	$0.5	10
		Wind Safety Savings	Corridor drivers	$15.7	13
		Economic Vitality:			
		Residual Value	NCDOT; Taxpayers	$51.0	13
		Travel Time Savings	All auto and truck drivers on the national network	$591.6	14
		Truck Vehicle Operating Savings	Truck drivers on the national network	$78.4	14
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 connected and autonomous vehicles. In addition, the corridor between Williamston and Whalebone will have real-time wind detection that will save lives and property damage.	Fiber Benefits	Households on the future I-87 and US 64 corridors	$5.2	15
		Autonomous Vehicles Benefit (Average Scenario)	Auto and truck drivers on the future I-87 and US 64 corridors	$65.4	16
		Detour Travel Time Savings**	Auto and truck drivers who do not need to detour for flooding events	$1.2	18
		Detour Truck Operating Savings**	Truck drivers who do not need to detour for flooding events	$0.2	18
		Detour Value of Trips not Taken**	Drivers who do not need to choose between detouring or making a trip in a flooding event	$22.1	19
The corridor is susceptible to flooding and needs resiliency improvements to raise the roadway out of flood prone areas, protect the corridor from flooding, and monitor the corridor for flooding events.	The resiliency features included in the Project will avoid detours when severe flooding may cause the future I-87 corridor to close for days at a time, saving travel time, vehicle operating costs, safety savings, emissions, and truck operating costs.	Detour Vehicle Operating Cost Savings**	Auto drivers who do not need to detour for flooding events	$0.7	19
		Flood Resiliency Repair Cost Savings	NCDOT; Taxpayers	$14.1	19
		Environmental			
		Emissions Savings (auto) [Includes diversions]	All residents and non-residents	$0.8	19
		Emissions Savings (truck) [Includes diversions]	All residents and non-residents	$1.4	20

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 2020 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 resiliency, auto emissions reductions, reducing the likelihood for accidents, providing new fiber internet connections to rural counties, reducing the need to detour during flood events, improving safety during high wind events, flood resiliency 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 20-year analysis horizon. The last element of US 64 would be constructed in 2024 and future I-87 in 2026; therefore an overall benefits period of 2025-2046 was used.

Benefits are estimated in accordance with guidance provided by US Department of Transportation (USDOT) for benefit-cost analysis. If no USDOT 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 2018 dollars discounted to 2020. 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-87_INFRA_2020BCA.xls) as well as in Table 2.

Table 2- BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Rate	3%	Sensitivity
Discount Year	2020	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs

[1] See INFRA 2020 Notice of Funding Opportunity, https://cms7.dot.gov/sites/dot.gov/files/docs/subdoc/1031/fy-2020-infra-notice-funding-opportunity-final-web.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	2018	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Operations Year	2027	
Deflator	See "Deflator" Sheet	https://www.whitehouse.gov/wp-content/uploads/2020/02/hist10z1_fy21.xlsx
Auto Occupancy	1.67	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
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	
Bridge gauges	36	NCDOT
Miles of I-87	179.1	GoogleMaps
Miles of US 64 Extension	93.7	GoogleMaps
Annual O&M Fiber (2018$)	$50,000	
Annual O&M ITS (2018$)	$100,000	
AADT Future I-87 (2018)	19,350	
Wake County	49,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Franklin County	29,000	
Nash County	23,500	
Edgecombe County	13,500	
Martin County	9,700	
Bertie County	13,000	
Chowan County	9,800	
Perquimans County	16,500	
Pasquotank County	13,500	
Camden County	16,000	
AADT Future I-87 (2002)	13,030	
Wake County (2003)	36,000	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
Franklin County (2003)	15,000	
Nash County	17,000	
Edgecombe County	9,100	
Martin County	7,500	
Bertie County	13,000	
Chowan County	7,500	
Perquimans County	12,000	

Pasquotank County (2003)	4,500	
Camden County	8,700	
AADT annual growth Future I-87 (2002-2018)	2.5%	
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	
E of SR 1342	14,000	
W of SR 1241	7,300	
E of SR 1229	2,600	
E of SR 1229	2,700	
W of US 264	3,400	
E of NC 345	19,000	
W of US 158	19,000	
AADT US 64 (2018)	9,822	
E of SR 1500	7,900	http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1
W of 64 Bus	8,300	
E of SR 1342	13,000	
W of SR 1241	7,500	
E of SR 1229	3,600	
E of SR 1229	3,700	
W of US 264	3,400	
E of NC 345	20,000	
W of US 158	21,000	
AADT annual growth US 64 (2002-2018)	0.49%	NCDOT
Economic Vitality		
Value of Time All Purposes, 2018$	$16.60	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Value of Time Truck, 2018$	$29.50	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Truck operating savings per hour (2018$)	$46.16	Table 9 ATRI Operational Cost of Trucking 2019. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance. Excludes driver time (valued in travel time savings); https://truckingresearch.org/wp-content/uploads/2019/11/ATRI-Operational-Costs-of-Trucking-2019-1.pdf
Vehicle Operating Cost per mile (2018$), auto	$0.41	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Safety		
O- No injury (2018$)	$3,200	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
C - possible injury (2018$)	$63,900	
B - non-incapacitating injury (2018$)	$125,000	
A - incapacitating (2018$)	$459,100	
K - killed (2018$)	$9,600,000	
U - Injured (severity unknown) (2018$)	$174,000	
# Accidents Reported (unknown if injured) (2017$)	$132,200	

Injury Crash (2018$)	$250,600	
Fatal Crash (2018$)	$10,636,600	
PDO per vehicle (2018$)	$4,400	
Environmental		
VOC Value of Emissions (2018$) per short ton	$2,100	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
NOx Value of Emissions (2018$) per short ton	$8,600	
PM Value of Emissions (2018$) per short ton	$387,300	
SOx Value of Emissions (2018$) per short ton	$50,100	
Passenger Car Emission Rates per Mile, VOC, 2013-2024	0.6	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, Nox, 2013-2024	0.91	
Passenger Car Emission Rates per Mile, PM25, 2013-2024	0.01	
Passenger Car Emission Rates per Mile, CO2, 2013-2024	532	
Passenger Car Emission Rates per Mile, VOC, 2025-2034	0.27	
Passenger Car Emission Rates per Mile, Nox, 2025-2034	0.28	
Passenger Car Emission Rates per Mile, PM25, 2025-2034	0.01	
Passenger Car Emission Rates per Mile, CO2, 2025-2034	434	
Passenger Car Emission Rates per Mile, VOC, 2035-	0.21	
Passenger Car Emission Rates per Mile, Nox, 2035-	0.2	
Passenger Car Emission Rates per Mile, PM25, 2035-	0.01	
Passenger Car Emission Rates per Mile, CO2, 2035-	397	
Passenger Car Gasoline Consumption Per mile	0.04149	http://www.epa.gov/otaq/consumer/420f08024.pdf
Short tons per Metric Ton	1.1015	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
LDGV Emissions Rates g/hr VOC	2.683	nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT
LDGV Emissions Rates g/hr NOX	3.515	nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT
Truck Emissions Rate g per hour VOC (average of 8a and 8b trucks)	3.868	https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs
Truck Emissions Rate g per hour Nox (average of 8a and 8b trucks)	39.0515	
Truck Emissions Rate g per hour PM2.5 (average of 8a and 8b trucks)	1.092	
Truck Emissions Rate g per hour PM10 (average of 8a and 8b trucks)	1.187	
Social Cost of Carbon		
	2018$ per metric ton	
2017	$1.00	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
2020	$1.00	
2025	$1.00	
2030	$1.00	
2035	$2.00	
2040	$2.00	
2045	$2.00	

2050	$2.00	

The analysis assumes that construction delays would result from 20 mph lower average speeds on future I-87 for five years and on US 64 for two years.

A key assumption in the analysis is the frequency of potential flooding events. The Project would allow for better monitoring of flooding. 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 resiliency 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. Between 1999 and 2018, the state was 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. However, for this analysis, the *actual* frequency of the 500-year storms was used; in other words, because the state 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 benefits 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. The values of crashes avoided are shown in Table 2.

Reduced Highway Fatalities and Crashes

Future I-87

Based on annual crash reductions 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 0.7 fatal (K), 1.23 fatal/injury, 46.3 injury A, B, and C, and 79.8 property damage only (PDO) crashes avoided per year. The distribution of expected injury types is important because each type of injury has a different associated economic cost (Table 3). These safety reductions were

[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.

applied in 2035 and assumed to grow proportional to the future I-87 traffic, or 2.5 percent per year as shown in Table 2.

Table 3 – I-87 Crash Reductions, 2035

	Annual Crash Reduction (Number of Crashes), 2035					
Project	**K**	**A**	**B**	**C**	**PDO**	**Total**
I-87						
I-6007	0	0	0.3	1.3	3	4.6
I-6005	0	0.2	0.6	20.2	48.8	69.8
H141265(a)	0.3	0.7	3.6	5.5	9	19.1
U-6149	0.3	0.7	3.5	5.5	13.3	23.3
H141265(b)	0.1	0.3	1.5	2.4	3	7.3
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

The total reduction in fatalities, injuries, and property damage is valued as $86.8 million, discounted at 7 percent.

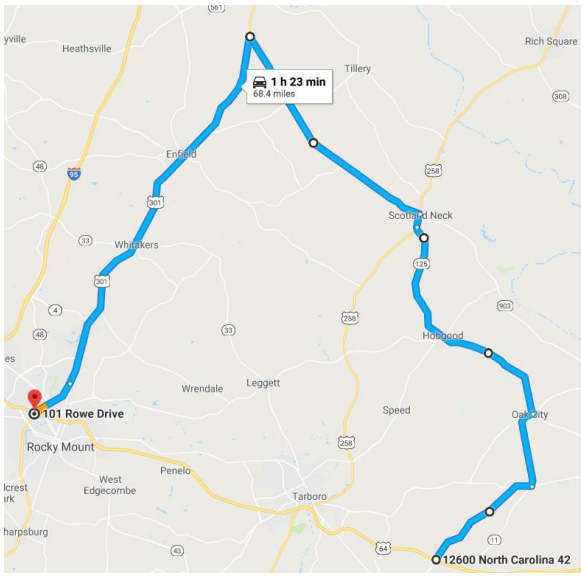
Detour Safety Savings

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 using a longer route, requiring additional travel time and mileage. The Project will eliminate flooding in these low-lying areas and therefore VMT will be reduced 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 12 hours. A summary of four of the seven detours is shown in Table 4. Note that there was no official detour issued for closures 1-3, so they are conservatively excluded from the analysis.

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

Figure 2 – Detour Route 4 around Tarboro and Princeville



Source: GoogleMaps

Table 4 – 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 2018. The VMT avoided by detours with the Project are shown in Table 5 .

Table 5 – Future I-87 Detour Vehicle Miles Travelled (VMT) and Vehicle Hours Travelled (VHT) Reduced by the Project

Year	VMT	VHT
2027	2,833,691	64,720
2028	2,904,598	66,340
2029	2,977,280	68,000
2030	3,051,780	69,701
2031	3,128,144	71,445
2032	3,206,419	73,233
2033	3,286,652	75,066
2034	3,368,894	76,944
2035	3,453,193	78,869
2036	3,539,602	80,843
2037	3,628,172	82,866
2038	3,718,959	84,939
2039	3,812,018	87,065
2040	3,907,406	89,243
2041	4,005,180	91,476
2042	4,105,401	93,765
2043	4,208,130	96,112
2044	4,313,429	98,517
2045	4,421,363	100,982
2046	4,531,998	103,509

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 2017 Crash Stats, as shown in Table 6.

Table 6 - Crashes by Type per 100,000,000 VMT

	Rate per 100,000,000 VMT
Fatalities	1.16
Injured persons	85

Source: USDOT, NHTSA Traffic Safety Facts 2017, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812806

PDO crashes are based on the share of fatal, injury, and PDO crashes over 2015-2017 that result in PDO from the USDOT's 2017 NHTSA Traffic Safety Facts. In total, 70.3 percent of crashes result in PDO; this share is held constant throughout the analysis period. The 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 USDOT 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 $4,400 (in 2018 dollars).

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 occurred in North Carolina over 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 $0.5 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[6] 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 every five years.[7] The frequency of an extreme wind event storm was estimated based on North Carolina Climate Office records[8] 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 $15.7 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 20-year analysis period, because the useful life of these elements is longer than 20 years. Highways and streets have a useful life of 60 years, and sewer systems (utilities) also have a useful life of 60 years,[9] while land does not depreciate. Fiber optic cable has been found to have a long useful life ranging from 40 to 100 years; this analysis uses 40 years.[10] Assuming straight-line depreciation for all assets besides land, the value of land was added to the total value of the

[6] 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
[7] National Hurricane Center Tropical Cyclone Report, Hurricane Hermine (AL092016), January 30, 2017, https://www.nhc.noaa.gov/data/tcr/AL092016_Hermine.pdf
[8] 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
[9] 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
[10] Sumitomo Electric Lightwave, Optical Fiber Cable Design & Reliability, http://www.ieee802.org/3/bm/public/may14/vanvickle_01_0514_optx.pdf

other assets and discounted from in the final year of the analysis period (2046). The residual value for the future I-87 corridor discounted at 7 percent is $49.8 million.

US 64

Installation of fiber optic cable along the US 64 corridor would have residual value after the end of the 20-year analysis period, because the useful life of fiber is longer than 20 years. Fiber optic cable has been found to have a long useful life ranging from 40 to 100 years; this analysis uses 40 years.[11] Assuming straight-line depreciation and discounted from in the final year of the analysis period (2044), the residual value for US 64 discounted at 7 percent is $1.2 million.

Travel Time Savings

Future I-87

Based on the North Carolina Statewide Travel Demand Model (SWM), improvements to the future I-87 corridor 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 2043 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 ($29.50 per hour) results in the truck time savings. The remaining traffic was multiplied by the auto occupancy rate (1.67) and the value of auto time for all purposes ($16.60 per hour). The travel time savings on future I-87 amounts to $591.6 million discounted at 7 percent.

Delays During Construction

Future I-87

Construction delays are estimated for the future I-87 corridor assuming a reduction in average travel speeds of 20 mph for the five years of construction.[12] The travel time loss is applied to all corridor drivers during the construction period and results in a cost of nearly $5.2 million on the future I-87 corridor. The delay cost is inclusive of the value of time and truck operating costs.

US 64

Construction delays are estimated for the US 64 corridor assuming a reduction in average travel speeds of 20 mph for the two years of construction. The travel time loss is applied to all US 64 corridor drivers during the construction period and results in a cost of nearly $1.0 million, inclusive of the value of time and truck operating costs.

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,[13] which is inclusive of fuel, oil, truck/trailer lease, maintenance, driver benefits, tires, and insurance and totals $46.16

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[11] Sumitomo Electric Lightwave, Optical Fiber Cable Design & Reliability, http://www.ieee802.org/3/bm/public/may14/vanvickle_01_0514_optx.pdf

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

[13] Table 9 ATRI Operational Cost of Trucking 2019. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance.

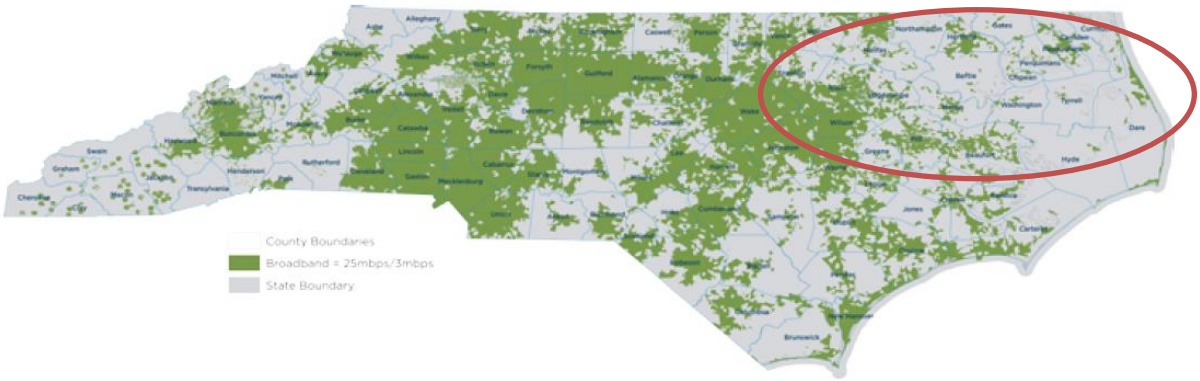
per hour. Driver time was excluded because it was already included in the Travel Time Savings benefit.

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 $78.4 million discounted at 7 percent.

Fiber Optic Cable 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 3 highlights the geographic pattern of high-speed connectivity in the state and the large gaps in service in the Project area (approximately in the area circled in red). 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.

Figure 3 - Broadband Availability at 25 MBPS Download Speeds



Source: Connecting North Carolina, State Broadband Plan, 2016. The approximate study area is circled.

The installation of fiber optic cable 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.

Future I-87

The Project will install fiber optic cable 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,[14] the value of an increase in broadband internet up to at least 4 megabytes per second (MBPS) is worth $10.61. 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

[14] 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. Adjusted from 2017 dollars to 2018 dollars using the GDP deflator.

outside of the urbanized areas[15] 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).[16] The total fiber benefit for future I-87 amounts to $3.4 million discounted at 7 percent.

US 64

The Project will install fiber optic cable 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.[17] The total fiber benefit for the eastern segment of US 64 amounts to $1.8 million discounted at 7 percent.

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 2026 on the future I-87 corridor and 2025 on US 64. As smart vehicles become 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,[18] 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 ten 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 optic cable installation. An adoption curve for the equipped-vehicles was assumed to be 8.4 percent in year 1 (2025) and increases to 85.9 percent by 2046. The adoption percent by year is consistent between the two corridors. The analysis 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 conservative 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 to 43 percent by the end of the analysis period. The cost and benefits adoption curves are shown in Table 7.

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[15] Excluded counties: Wake, Franklin, Nash, and Edgecombe.

[16] NC Management and Budget, https://files.nc.gov/ncosbm/demog/countygrowth_cert_2016.html

[17] Ibid.

[18] "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

Table 7 – Autonomous Vehicles Adoption Curves for Costs and Benefits

Year	Costs: Adoption Curve	Benefits: Low Ramp-up
2025 – Year 1 for US 64	8.4%	0%
2026	11.5%	1%
2027 – Year 1 for future I-87	14.5%	1%
2028	17.6%	2%
2029	20.6%	3%
2030	23.7%	4%
2031	26.7%	6%
2032	29.8%	7%
2033	32.8%	8%
2034	35.9%	10%
2035	38.9%	11%
2036	45.0%	13%
2037	49.1%	16%
2038	53.2%	20%
2039	57.3%	25%
2040	61.4%	27%
2041	65.5%	31%
2042	69.5%	34%
2043	73.6%	36%
2044 – year 20 for US 64	77.7%	38%
2045	81.8%	41%
2046 – year 20 for future I-87	85.9%	43%

High and average benefits ramp-up scenarios were also estimated, which assume benefits accrue faster than the low scenario. 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 ten years, the net new vehicles are multiplied by the approximately $2,000 cost per vehicle.

Based on the AADT in the corridor in 2027 (about 24,170), the share of national benefits estimated for autonomous vehicles was shared down by a ratio of 24,170 vehicles compared to the national 250 million cars on the road. For future I-87, this represents 0.009 percent, or $130 million annually in 2018 dollars. 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 $44.3 million discounted at 7 percent.

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 ten years, the net new vehicles are multiplied by the approximately $2,000 cost per vehicle.

Based on the AADT in the corridor in 2025 (about 10,161), the share of national benefits estimated for autonomous vehicles was shared down by a ratio of 10,161 vehicles compared to the national 250 million cars on the road. For US 64 this represents 0.004 percent, or $57 million annually in 2018 dollars. 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 US 64 amounts to $21.1 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 using 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 reduced 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 4. 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 $1.2 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 $46.16 is based on the ATRI Operational Cost of Trucking,[19] 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

[19] Table 9 ATRI Operational Cost of Trucking 2019. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance.

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.

Detour Value of Trips not Taken

There is value in trip-making; otherwise trips would not be made. Likewise, there is a value for 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.[20] 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 $22.1 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 $0.41 per mile in 2018 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 $0.7 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 64 (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 $14.1 million.

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.[21] The tons of reduced emissions were monetized using the recommended value of emissions 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 $0.8 million, discounted at 7 percent.

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

[21] 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

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,[22] the tons of VOC, NOX, and particulate matter with a diameter less than 2.5 micrometers (PM2.5), were estimated. The tons of reduced emissions were monetized using the recommended value of emissions from INFRA 2020 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 $1.4 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, resiliency, soft costs, and contingency. The costs of the project elements are shown in Table 8.

Table 8 – Future I-87 Construction Costs, in 2019 dollars

STIP #	Project Build Cost (R, U, C, Res)	Right-of-Way Cost	Utilities Cost	Construction Cost	Resiliency 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
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
H171801	$30,900,000	$600,000	$500,000	$29,800,000	$0
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
Resiliency*	$4,000,000	$0	$0	$0	$4,000,000
Total	**$499,100,000**	**$29,500,000**	**$7,400,000**	**$457,200,000**	**$5,000,000**

Source: NCDOT
Note: values in table are rounded; *resiliency costs are shown rounded additionally to $4,000,000 in the narrative

The capital costs are applied over a five year construction period, beginning in 2022 and ending in 2026.

The resiliency elements of the project include vulnerability assessments, stress testing, FIMANT, Bridgewatch, adding gauges on bridges and culverts, and rock plating the roadway embankment near exit 487 on US 64 near Princeville. The resiliency items total $4.0 million and will be constructed over seven years from 2020-2026.

Previously incurred costs for professional engineering (PE) are estimated at $797,812 in 2018 dollars, and were assumed to have been spent in 2019.

[22] 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.

The capital costs were converted from 2019 dollars to 2018 dollars and discounted at 7 percent; the total capital costs for future I-87 are $353.0 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 9.

Table 9 – US 64 Construction Costs, in 2019 dollars

STIP #	Project Build Cost (R, U, C, Res)	Right-of-Way Cost	Utilities Cost	Construction Cost	Resiliency Cost
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 2023 and ending in 2024. The capital costs were converted from 2019 dollars to 2018 dollars and discounted at 7 percent; the total capital costs for US 64 are $11.6 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 2027, 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 optic cable are assumed to require minimal maintenance annually, estimated at $100,000 and $50,000 per year, respectively. The FIMANT/Bridgewatch and gauge elements of the resiliency projects require annual operating costs of $249,000.

The total O&M costs over the analysis period and discounted at 7 percent is $6.1 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 2025, as the first full year of operation.

The total O&M costs over the analysis period and discounted at 7 percent is $1.2 million.

Summary

Table 10 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 $921.8 million dollars of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 2.53, a solid return on these critical investments. The net benefits total $557.2 million.

In addition, both of the project elements – future I-87 and US 64 – also have greater benefits than costs. Future I-87 has net benefits of $531.3 million and US 64 has $26.0 million net benefits, resulting in BCRs of 2.51 and 3.24 respectively. The BCA for the individual project elements is shown in Table 11 and Table 12.

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 corridor's resiliency 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 10 – Total Project Benefit-Cost Analysis (2025-2046 in 2018 $M)

	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$364.6	$430.6
Total Costs	***$364.6***	***$430.6***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	$86.8	$158.0
Detour Safety Savings**	$0.5	$0.9
Wind Safety Savings	$15.7	$25.7
Sub-Total Safety Benefits	***$103.1***	***$184.7***
Economic Vitality		
Residual Value	$51.0	$137.1
Travel Time Savings	$591.6	$1,156.1
Delays During Construction	-$6.1	-$7.1
Truck Vehicle Operating Savings	$78.4	$153.2
Fiber Benefits	$5.2	$8.9
Autonomous Vehicles Benefit (Low Scenario)	$65.4	$193.9
Detour Travel Time Savings**	$1.2	$2.2
Detour Truck Operating Savings**	$0.2	$0.3
Detour Value of Trips not Taken**	$22.1	$40.2
Detour Vehicle Operating Cost Savings**	$0.7	$1.3
Flood Resilience Repair Cost Savings	$14.1	$24.9
Sub-Total Economic Vitality	***$823.9***	***$1,711.1***
Environmental		
Emissions Savings (auto) [Includes diversions**]	$0.8	$1.5
Emissions Savings (truck) [Includes diversions**]	$1.4	$2.8
Sub-Total Environmental	***$2.2***	***$4.3***
O&M Costs	-$7.3	-$13.8
Net O&M	***-$7.3***	***-$13.8***
Total Benefits	***$921.8***	***$1,886.3***
BC Ratio	**2.53**	**4.38**
Net Present value	**$557.2**	**$1,455.7**

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

Table 11 – Future I-87 Benefit-Cost Analysis (2027-2046 in 2018 $M)

	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$353.0	$417.3
Total Costs	***$353.0***	***$417.3***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	$86.8	$158.0
Detour Safety Savings**	$0.5	$0.9
Wind Safety Savings	NA	NA
Sub-Total Safety Benefits	***$87.4***	***$159.0***
Economic Vitality		
Residual Value	$49.8	$134.1
Travel Time Savings	$591.6	$1,156.1
Delays During Construction	-$5.2	-$6.0
Truck Vehicle Operating Savings	$78.4	$153.2
Fiber Benefits	$3.4	$6.0
Autonomous Vehicles Benefit (Low Scenario)	$44.3	$136.6
Detour Travel Time Savings**	$1.2	$2.2
Detour Truck Operating Savings**	$0.2	$0.3
Detour Value of Trips not Taken**	$22.1	$40.2
Detour Vehicle Operating Cost Savings**	$0.7	$1.3
Flood Resilience Repair Cost Savings	$14.1	$24.9
Sub-Total Economic Vitality	***$800.8***	***$1,649.1***
Environmental		
Emissions Savings (auto) [Includes diversions**]	$0.8	$1.5
Emissions Savings (truck) [Includes diversions**]	$1.4	$2.8
Sub-Total Environmental	***$2.2***	***$4.3***
O&M Costs	-$6.1	-$11.8
Net O&M	***-$6.1***	***-$11.8***
Total Benefits	***$884.2***	***$1,800.6***
BC Ratio	**2.51**	**4.31**
Net Present value	**$531.3**	**$1,383.2**

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

Table 12 – US 64 Project Benefit-Cost Analysis (2025-2044 in 2018 $M)

	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	$11.6	$13.3
Total Costs	***$11.6***	***$13.3***
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	NA	NA
Detour Safety Savings**	NA	NA
Wind Safety Savings	$15.7	$25.7
Sub-Total Safety Benefits	***$15.7***	***$25.7***
Economic Vitality		
Residual Value	$1.2	$3.0
Travel Time Savings	NA	NA
Delays During Construction	-$1.0	-$1.1
Truck Vehicle Operating Savings	NA	NA
Fiber Benefits	$1.8	$2.9
Autonomous Vehicles Benefit (Low Scenario)	$21.1	$57.3
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	***$23.1***	***$62.0***
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	-$1.2	-$2.0
Net O&M	***-$1.2***	***-$2.0***
Total Benefits	***$37.6***	***$85.7***
BC Ratio	**3.24**	**6.46**
Net Present value	**$26.0**	**$72.5**

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

List of Supporting Information

AECOM, NCDOT_I-87_INFRA_2020BCA.xls (Excel spreadsheet with BCA calculations by benefit type and summary)

AECOM Safety Analysis.pdf

ATRI Operational Cost of Trucking 2019, https://truckingresearch.org/wp-content/uploads/2019/11/ATRI-Operational-Costs-of-Trucking-2019-1.pdf

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