# Technical Memorandum: Benefit-Cost Analysis of the I-95 Resiliency and Innovative Technology Improvements Project

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| Date: | July 15, 2019 |
| Subject: | Benefit-Cost Analysis for the I-95 Resiliency and Innovative Technology Improvements Project |

## Project Description

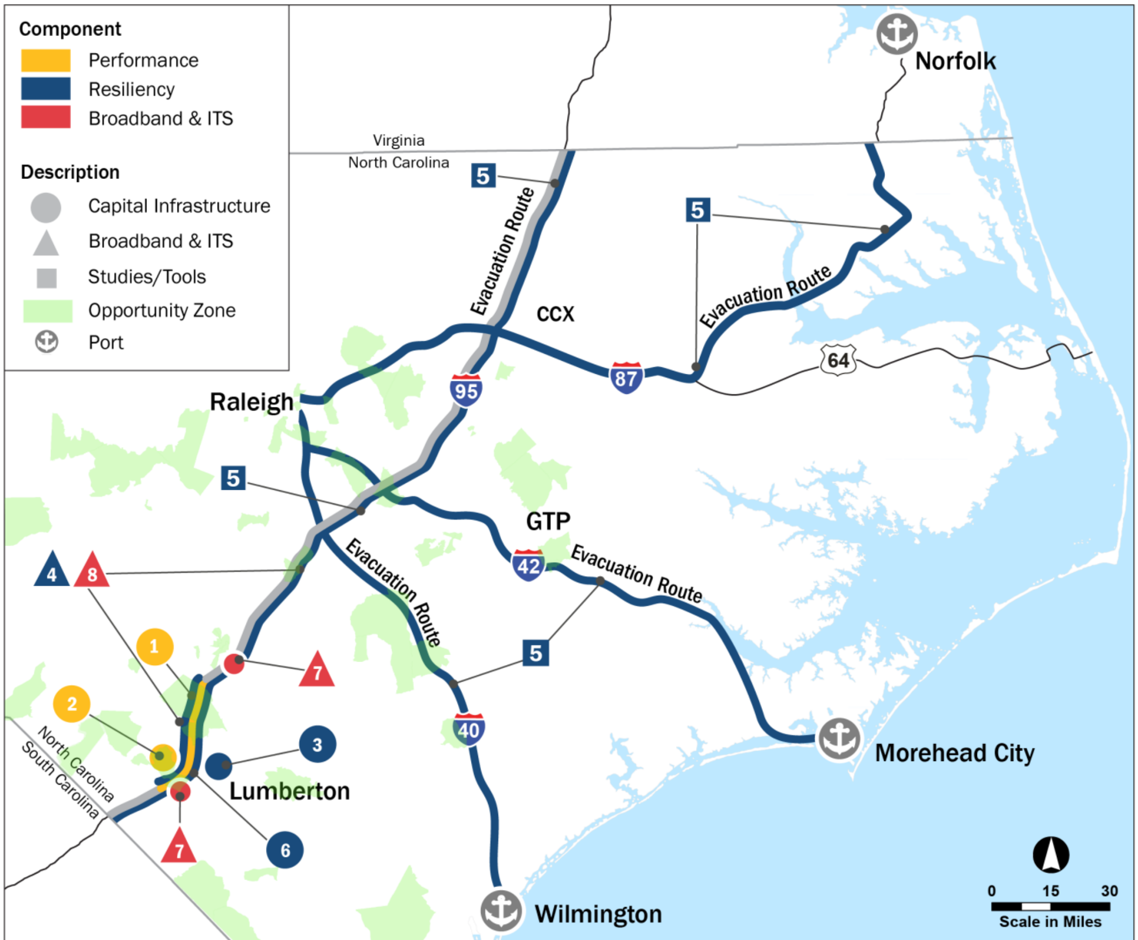
The *I-95 Resiliency and Innovative Technology Improvements* (hereafter called the "Project") is comprised of improvements to I-95, including upgrading a 27-mile segment of the facility into a state of good repair and up to current design standards, adding capacity, and improving safety on this national 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 Project includes the following elements:

- 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 gauges on bridges and culverts to monitor flooding
- Conduct stress testing along the corridor
- Operate FITRANS/Bridgewatch systems

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<br>② Interchange project at exit 19 (Carthage Road) |
| **Resiliency** | I-95 | ③ Extending and raising two bridges crossing the Lumber River near exit 19<br>④ Add flood gauges for enhanced FITRANS performance from I-74 to Robeson/Cumberland County line<br>⑤ Implement stress test of interstate and primary routes (pursuing flood model partnership with Netherlands) along the interstate<br>⑥ Raise road elevation between exits 17-19 and 20-21 |
| | I-95 Evacuation Routes (Future I-87, Future I-42, & I-40) | ⑤ Implement stress test of interstate and primary routes (pursuing flood model partnership with Netherlands) |
| **Broadband & ITS** | I-95 | ⑦ Install ITS devices on flood prone areas for rerouting along Lumber River and Cape Fear River crossings<br>⑧ Install broadband connecting flood gauges with existing I-95 broadband network |

### 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 |
|---|---|---|---|---|---|
| I-95 near Lumberton experiences congestion and had extreme flooding during recent hurricanes, which causes delays and major detours for long periods of time.<br><br>The corridor is susceptible to flooding and needs resilience improvements to raise the roadway out of flood prone areas, protect the corridor from flooding, and monitor and plan for flooding events. | 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.<br><br>The resilience features included in the Project will avoid detours when severe flooding closes I-95 for days at a time, saving travel time, vehicle operating costs, safety savings, emissions, and truck operating costs. | Safety: | | | |
| | | Reduced Highway Fatalities and Crashes | Corridor drivers | $87.2 | 8 |
| | | Detour Safety Savings** | Auto and truck drivers who do not need to detour for flooding events | $30.4 | 8 |
| | | Economic Competitiveness: | | | |
| | | Travel Time Savings | All auto and truck drivers on the national network | $1,316.7 | 11 |
| | | Delays During Construction | All auto and truck drivers on I-95 in project segments | -$15.3 | 12 |
| | | Truck Vehicle Operating Savings | Truck drivers on the national network | $451.6 | 12 |
| | | Detour Travel Time Savings** | Auto and truck drivers who do not need to detour for flooding events | $51.4 | 12 |
| | | Detour Truck Operating Savings** | Truck drivers who do not need to detour for flooding events | $17.6 | 12 |
| | | Detour Value of Trips not Taken** | Drivers who do not need to choose between detouring or making a trip in a flooding event | $212.5 | 13 |
| | | Detour Vehicle Operating Cost Savings** | Auto drivers who do not need to detour for flooding events | $36.4 | 13 |
| | | State of Good Repair: | | | |
| | | Residual Value | NCDOT; Taxpayers | $25.0 | 13 |
| | | Flood Resilience Repair Cost Savings | NCDOT; Taxpayers | $0.5 | 13 |
| | | Environmental Sustainability: | | | |
| | | Emissions Savings (auto) [Includes diversions] | All residents and non-residents | $1.5 | 14 |
| | | Emissions Savings (truck) [Includes diversions] | All residents and non-residents | $9.0 | 14 |

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

## Introduction

This technical memorandum estimates the long-term benefits associated with the Project. The long-term benefits presented relate to five goals identified in the BUILD 2019 Notice of Funding Opportunity (NOFO):[1] Safety, Economic Competitiveness, State of Good Repair, Environmental Sustainability, and Quality of Life. 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, reducing the need to detour during flood events, and flood resilience repair cost savings.

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 BUILD 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 (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 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 BCA.xlsx) 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 |
| Dollar Year | 2017 | 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs |
| Deflator | See "Deflator" | https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/hist10z1.xls |

[1] See BUILD 2019 Notice of Funding Opportunity, https://www.transportation.gov/sites/dot.gov/files/docs/subdoc/391/fy-2019-build-nofo-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 corridor's 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.

| | Sheet | |
|---|---|---|
| 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. |
| 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 its 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 | |
| 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 |
| **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 | $8,300 | 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs |
| PM2.5 Value of Emissions (2017$) 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 |
| **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 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.

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 two 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. 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

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

injury has a different associated economic cost. Each fatal/injury crash avoided was valued at $174,000 for U – Injured (severity unknown), and $3,200 for O – No Injury (or PDO).

### *Reduced Highway Fatalities and Crashes*

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 more than 56 fatalities and injuries, and 228 PDO crashes avoided per year. These crash reductions were held constant throughout the analysis period and conservatively assume one person or vehicle is involved in each crash.

The crash reduction factors shown in Table 3 were valued based on the KABCO score.

**Table 3 – 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.

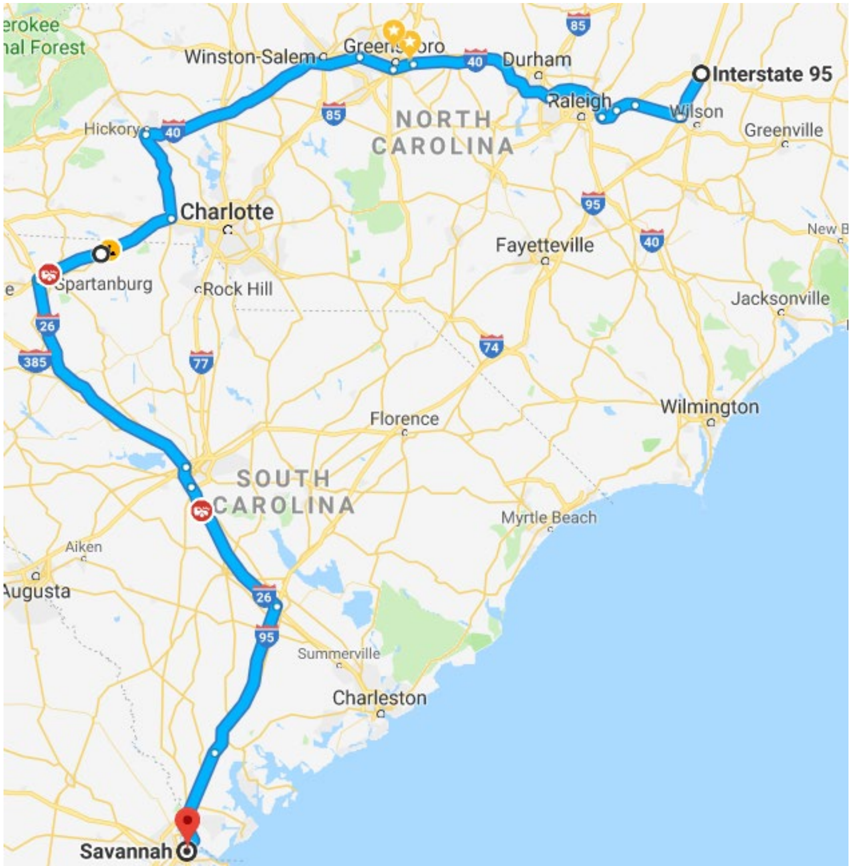
The total reduction in fatalities and crashes was valued as $87.2 million, discounted at 7 percent.

### *Detour Safety Savings*

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 2 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.[4] 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 4.

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

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




Source: GoogleMaps

**Table 4 – 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 5.

### Table 5 – 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 6.

**Table 6 - 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 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.

## ***Economic Competitiveness***

### *Travel Time Savings*

The I-95 travel time savings were estimated using a methodology that combined the North Carolina Statewide Model (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. 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.[5]

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 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 I-95 corridor assuming a reduction in average travel speeds of 20 mph for the four years of construction.[6] The travel time loss is applied to all corridor drivers during the construction period and results in a cost of $15.3 million. The delay cost is inclusive of the value of time and truck operating costs.

### *Truck Vehicle Operating Savings*

The travel time savings on I-95 results in operating cost savings for trucks. The operating cost per hour for trucks was found in the ATRI Operational Cost of Trucking,[7] 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 (22 percent) and the truck operating cost per hour results in the truck operating savings. The total operating time savings for trucks amounts to $451.6 million discounted at 7 percent.

### *Detour Travel Time Savings*

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 2 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 4.

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 I-95 amounts to $51.4 million discounted at 7 percent.

### *Detour Truck Operating Savings*

The travel time savings from the detours avoided on I-95 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,[8] 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

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[5] 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.

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

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

[8] Ibid.

total detour travel time savings by the truck percentage (22 percent) and the truck operating cost per hour results in the detour truck operating savings. The total operating time savings for detoured trucks 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.[9] 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.

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. 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

Vehicle operating cost savings result from avoiding auto detours during flooding events in the corridor. 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, 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.

## State of Good Repair

### Residual Value

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 the final year of the analysis period (2055). The residual value for the Project discounted at 7 percent is $25.0 million.

### Flood Resiliency Repair Cost Savings

The resiliency projects 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[11] 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.

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

[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

[11] 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.

## ***Environmental Sustainability***

### *Auto Emissions Savings*

Improvements to I-95 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.[12] The tons of reduced emissions were monetized using the recommended value of emissions from BUILD 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, the Project results in auto emissions savings of $1.5 million, discounted at 7 percent.

### *Truck Emissions Savings*

Based on the travel time savings, trucks also save time when the Project is operational. Based on emissions rates per idling hour as found in EPA guidance,[13] the tons of VOC, NOx, 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 BUILD 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 total $9.0 million, discounted at 7 percent.

## ***Quality of Life***

The Project will reduce congestion in this highly-traveled portion of the I-95 corridor, reducing lost time in traffic jams. The resiliency improvements including water gauges, stress testing, FITRANS/Bridgewatch, and running fiber from the I-95 corridor to gauges do not prevent overall flooding, but they will ensure that the road system is available for evacuation before and emergency response following the storm. Crews can get out and assess the situation and respond more quickly with a resilient road system.

# Costs

### *Capital Costs*

The capital costs for the Project include the costs for the purchase of land, utilities, construction, resilience, soft costs, and contingency. The costs of the project roadway elements are shown in Table 7.

**Table 7 – 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 | $375,000,000 | $32,000,000 | $1,000,000 | $342,000,000 | $0 |
| I-5879 | $12,940,000 | $540,000 | $0 | $12,400,000 | $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

[12] 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

[13] 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 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 10 gauges on bridges and culverts, extending fiber to connect the gauges to the I-95 fiber trunk line, and stress testing. The resilience items total $1.6 million in 2017 dollars and will be constructed over two years from 2020-2021.

Previously incurred costs for professional engineering (PE) are estimated at $3.3 million 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 are $501.5 million.

### *Operating and Maintenance Costs*

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 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 and gauges elements of the resilience projects require annual operating costs of $750,000 and $15,000 annually, respectively.

The total O&M costs over the analysis period and discounted at 7 percent is $14.9 million.

## Summary

Table 8 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 $2.2 billion dollars of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 4.41, a solid return on these critical investments. The net benefits total $1.7 billion.

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

| | Discounted at 7% | Discounted at 3% |
|---|---|---|
| **Costs** | | |
| Capital Costs | $501.5 | $585.0 |
| ***Total Costs*** | ***$501.5*** | ***$585.0*** |
| | | |
| **Benefits** | | |
| **Safety** | | |
| Reduced Highway Fatalities and Crashes | $87.2 | $54.5 |
| Detour Safety Savings** | $30.4 | $66.4 |
| ***Sub-Total Safety*** | ***$117.6*** | ***$120.9*** |
| **Economic Competitiveness** | | |
| Travel Time Savings | $1,316.7 | $2,852.6 |
| Delays During Construction | -$15.3 | -$18.2 |
| Truck Vehicle Operating Savings | $451.6 | $978.4 |
| 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 |
| ***Sub-Total Economic Competitiveness*** | ***$2,070.8*** | ***$4,506.7*** |
| **State of Good Repair** | | |
| Residual Value | $25.0 | $98.4 |
| Flood Resilience Repair Cost Savings | $0.5 | $1.0 |
| ***Sub-Total State of Good Repair*** | ***$25.5*** | ***$99.4*** |
| **Environmental Sustainability** | | |
| Emissions Savings (auto) [Includes diversions**] | $1.5 | $3.2 |
| Emissions Savings (truck) [Includes diversions**] | $9.0 | $19.5 |
| ***Sub-Total Environmental Sustainability*** | ***$10.5*** | ***$22.7*** |
| **Quality of Life** | | |
| ***Sub-Total Quality of Life*** | ***$0.0*** | ***$0.0*** |
| O&M Costs | -$14.9 | -$29.4 |
| ***Net O&M*** | ***-$14.9*** | ***-$29.4*** |
| | | |
| ***Total Benefits*** | ***$2,209.5*** | ***$4,720.3*** |
| | | |
| **BC Ratio** | **4.41** | **8.07** |
| **Net Present value** | **$1,708.0** | **$4,135.3** |

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

## List of Supporting Information

AECOM, BCA.xlsx (Excel spreadsheet with BCA calculations by benefit type and summary)

AECOM Safety Analysis.pdf

AECOM Storms That Have Directly Hit or Affected North Carolina.xlsx

AECOM Travel Demand Model Methodology.pdf

ATRI Operational Cost of Trucking 2018

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

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

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

NCDOT Annual Average Daily Traffic, http://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=b7a26d6d8abd419f8c27f58a607b25a1

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

U.S. DOT, 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/14091/benefit-cost-analysis-guidance-2018.pdf

U.S. DOT, 2013, Federal Transit Administration, New and Small Starts Evaluation and Rating Process Final Policy Guidance, August 2013

U.S. DOT, BUILD 2019 Notice of Funding Opportunity, https://www.transportation.gov/sites/dot.gov/files/docs/subdoc/391/fy-2019-build-nofo-fr.pdf

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

Excel O&M Sources from NCDOT:

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, I95 Florence Detour List.docx