Technical Memorandum: Benefit-Cost Analysis of the US 74 Corridor Opportunities for Rural Efficiency and Safety Improvement (CORESI) Project

Date: February 25, 2020

Subject: Benefit-Cost Analysis for the US 74 Corridor Opportunities for Rural Efficiency and Safety Improvement (CORESI) Project

Project Description

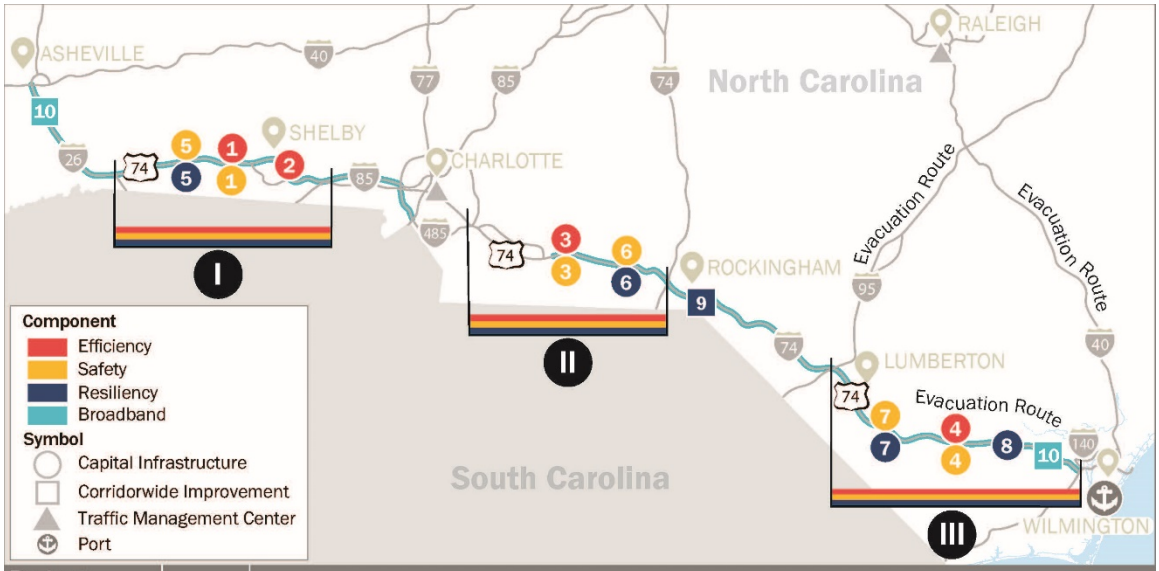
US Route 74 (US 74) is a critical east-west freight corridor in North Carolina that runs from Chattanooga, Tennessee to Wilmington, North Carolina. US 74 stretches from the rural mountainous region of western North Carolina to the port in Wilmington, connecting Asheville, Shelby, Charlotte, Rockingham, Lumberton, and Wilmington. The Corridor Opportunities for Rural Efficiency and Safety Improvement (CORESI) Project includes the following elements:

- Shelby Bypass: Construct a freeway bypass around Shelby. Benefits associated with this portion of the Project will be realized in 2027.
- R-4045 Interchange: Upgrade an at-grade intersection to an interchange. Benefits associated with this portion of the Project will be realized in 2027.
- R-5797 Interchange: Upgrade an at-grade intersection to an interchange. Benefits associated with this portion of the Project will be realized in 2024.
- R-5819 Overpass: Upgrade an at-grade interchange to an overpass. Benefits associated with this portion of the Project will be realized in 2025.
- R-5820 Interchange: Upgrade an at-grade intersection to an interchange. Benefits associated with this portion of the Project will be realized in 2025.
- R-5721 Interchange: Upgrade an at-grade intersection to an interchange. Benefits associated with this portion of the Project will be realized in 2026.
- Corridor Wide Improvements: Install fiber optic cable in the Project right-of-way (ROW), install ITS equipment between Charlotte and Rockingham, and construct resiliency enhancements. Benefits associated with this portion of the Project will be realized in 2025.

Fiber optic cable will be installed in the ROW along US 74, traversing the length of US 74 from Wilmington to Asheville. 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 US 74 and allow the state to exchange access to the highway ROW for private telecommunications capacity to fill gaps in access to high-speed communications in rural 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 Asheville and Wilmington will have resiliency components, including flood monitoring systems that allow NCDOT to monitor water levels and close bridges and roads when conditions warrant, saving lives and property damage. The resiliency features included in the Project will support emergency management officials' ability to mitigate, respond to, and recover from natural disasters. The components of the Project have independent utility, but the greatest benefits are realized when the investments are made together. 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.

Table 2 demonstrates the cost-effectiveness of each individual Project component.

Figure 1– Project Elements



Project Component	Section	Description
Efficiency	I	1 Interchange project at Lattimore Road/N Academy Street (R-4045) 2 Completion of remaining sections of Shelby Bypass (R-2707D & R-2707E)
	II	3 Monroe, Marshville, Wadesboro Signal Systems Synchronization
	III	4 Interchange projects at Boardman Road, Chauncey Town Road, and NC 72/NC 130 (R-5797, R-5751, R-5820). Conversion of at-grade intersection to an overpass at Old Lake Road (R-5819)
Safety	I	1 See description above (Efficiency) 5 ITS traffic incident/event management capital improvements to include dynamic message board signs for real-time communication with roadway users and traffic cameras for real-time remote traffic monitoring
	II	3 See description above (Efficiency) 6 ITS traffic incident/event management capital improvements to include dynamic message board signs for real-time communication with roadway users and traffic cameras for real-time remote traffic monitoring
	III	4 See description above (Efficiency) 7 ITS traffic incident/event management capital improvements to include dynamic message board signs for real-time communication with roadway users and traffic cameras for real-time remote traffic monitoring
Resiliency	I	5 See description above (Safety)
	II	6 See description above (Safety)
	III	7 See description above (Safety) 8 Install ITS flood gauge devices in flood prone areas for real-time infrastructure monitoring and rerouting during weather events in Columbus and Brunswick Counties
	US 74 Corridor	9 Implement vulnerability assessments and stress tests of US 74 to test the performance of known flooding locations with a range of design storms to determine when and how long flooding occurs through intensive hydraulic modelling
Broadband	US 74 Corridor	10 Install broadband fiber in missing locations along US 74, I-85, I-485, and I-74

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%
US 74 is a critical east-west freight corridor that connects eastern Tennessee to Wilmington, North Carolina, facilitating the flow of goods and services between the rural Appalachian Mountain region to the Port of Wilmington. US 74 currently experiences congestion at pinch points across the corridor. Anticipated population and economic growth are expected to exacerbate congestion along the corridor.	The CORESI Project introduces a series of upgrades at critical bottleneck locations on US 74 across North Carolina. The North Carolina Department of Transportation has a long-term goal to upgrade the entire east-west corridor to Interstate standards. The CORESI Project reflects a fiscally responsible approach to achieving this long-term objective. The CORESI Project consists of the following components: • Shelby Bypass • R-4045 Interchange Upgrades • R-5797 Interchange Upgrades • R-5819 Overpass Upgrades • R-5820 Interchange Upgrades • R-5751 Interchange Upgrades In addition, corridor wide improvements will be made, including the installation of fiber optic cable along the entire corridor's right of way, installation of ITS signal coordination between Charlotte and Rockingham, and resiliency enhancements.	**Economic Vitality**		
		Travel Time Savings	Remaining corridor drivers and those using the bypass	$345.3
		Vehicle Operating Cost Savings	All corridor drivers and those using the bypass	$50.3
		Work Zone Impacts	All corridor drivers and those using the bypass	($38.3)
		Autonomous Vehicles	Autonomous vehicle passengers	$133.0
		Residual	NCDOT; taxpayers	$11.3
		Environmental		
		Reduced Emissions	All residents and non-residents	$1.1
		Safety		
		Reduced Accidents	All corridor drivers	$92.9

Table 2 - BCA Summary of Project Components

7% Discount Rate, $Millions	US 74 CORESI Project							
Benefit	**Shelby Bypass**	**R-4045 Interchange**	**R-5797 Interchange**	**R-5819 Overpass**	**R-5820 Interchange**	**R-5751 Interchange**	**Corridor Wide Improvements**	**Total**
Safety								
Reduced Accidents	$22.4	$2.6	$34.9	$0.5	$24.0	$1.3	$7.3	$92.9
Economic Vitality								
Travel Time Savings	$130.0	$9.0	$24.4	$11.0	$12.3	$15.1	$143.5	$345.3
Vehicle Operating Cost Savings	$13.0	$3.2	$4.5	$2.5	$2.7	$2.3	$22.2	$50.3
Work Zone Impacts	-$27.8	-$3.1	-$1.3	-$2.0	-$2.0	-$2.2		-$38.3
Autonomous Vehicles							$133.0	$133.0
Residual	$6.3	$0.7	$1.2	$0.6	$1.1	$0.8	$0.8	$11.3
O&M	-$5.9	-$0.1	$0.0	$0.0	$0.0	$0.0	-$3.3	-$9.3
Environmental								
Reduced Emissions	$0.6	$0.0	$0.1	$0.0	$0.0	$0.0	$0.3	$1.1
Total Benefits	**$138.7**	**$12.3**	**$63.6**	**$12.7**	**$38.0**	**$17.3**	**$303.7**	**586.3**
Costs								
First Costs	$117.4	$11.2	$22.9	$11.2	$21.4	$15.2	$33.4	$232.5
Total Costs	**$117.4**	**$11.2**	**$22.9**	**$11.2**	**$21.4**	**$15.2**	**$33.4**	**$232.5**
Benefit Cost Analysis								
Net Present Value	**$21.3**	**$1.2**	**$40.8**	**$1.4**	**$16.7**	**$2.1**	**$270.3**	**$353.8**
Benefit Cost Ratio	**1.2**	**1.1**	**2.8**	**1.1**	**1.8**	**1.1**	**9.1**	**2.5**

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 seven individual Project components in addition to the total improvements at 7 percent.

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, reducing emissions, enhancing safety, improving internet connectivity in rural counties, 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 critical investment. As directed in the INFRA guidance, the benefits of the capital investment have been estimated over a 30-year analysis horizon. The 30-year analysis period is used because the project components are new construction with component lifespans of 40 to 60 years. As described in the Project Description, benefits associated with individual Project elements will first be realized in 2024 and the last element of the Project's construction would be completed in 2026. An overall benefits period of 2024-2056 was used for the Project elements.

Benefits are estimated in accordance with guidance provided by U.S. Department of Transportation (U.S. DOT) for benefit-cost analysis. If no U.S. DOT guidance was available for the estimate, the Project team consulted industry research 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 US74_CORESI_BCA_Final.xls) as well as in Table 3.

Table 3- BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Year	2020	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Dollar Year	2018	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Deflator	See "Deflator" Sheet	https://www.whitehouse.gov/wp-content/uploads/2020/02/hist10z1_fy21.xlsx
Annualization Factor (days)	250	
Analysis Period (years)	30	

[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

Economic Vitality		
Value of Time		
Personal	$15.20	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Business	$27.10	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
All Purposes	$16.60	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Truck Drivers	$29.50	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Long Distance Intercity Personal	$21.30	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Long Distance Intercity All Purposes	$21.98	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Vehicle Operating Costs		
Vehicle operating costs per mile	$0.39	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Truck operating costs per mile	$1.17	Tables 9-10 ATRI Operational Cost of Trucking 2019; https://truckingresearch.org/wp-content/uploads/2019/11/ATRI-Operational-Costs-of-Trucking-2019-1.pdf [2]
Truck operating savings per hour	$46.16	
Vehicle Occupancy		
Passenger, Weekday Peak	1.48	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Passenger, Weekday Off-Peak	1.58	
Passenger, Weekend	2.02	
Passenger, All	1.67	
US 74 Shelby Bypass (2707 D/E)		
Start Year	2027	
Existing Length (miles)	16.8	
Bypass Length (miles)	18.6	
Increased Distance (miles)	1.8	
Bypass Daily Thru-Traffic (2045)	11,447	Regional Travel Demand Model
Bypass Truck Percentage	22%	Regional Travel Demand Model
Passenger Cars	8,906	
Trucks	2,541	
Diverted Thru-Traffic Without Project VMT (2045)	50,000,232	
Diverted Thru-Traffic with Project VMT (2045)	55,357,400	
Percent Thru-traffic >50 miles	68%	Regional Travel Demand Model
US 74 Non-Diverted Thru-Traffic (2045)	539	Regional Travel Demand Model
US 74 Non-Diverted Local Traffic (2045)	27,969	Regional Travel Demand Model
US 74 Truck Percentage	23%	Regional Travel Demand Model
US 74 Traffic Growth Rate	0.14%	Regional Travel Demand Model
US 74 Time Savings (minutes) (2045)	2.94	Regional Travel Demand Model
Distance impacted by Construction (miles)	3	
R-4045 Lattimore Interchange		

[2] Costs included are: fuel, truck/trailer lease payments, repair & maintenance, insurance premiums, tires, and driver benefits

Start Year	2027	
2018 US 74 Traffic Count	20,000	NC DOT Annual Average Daily Traffic Mapping Application http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280
2018 Lattimore Rd Traffic Count	950	
Truck Percentage	22%	Statewide Travel Demand Model
Traffic Growth Rate	0.14%	Statewide Travel Demand Model
Distance impacted by Construction (miles)	0.5	
R-5797 Boardman Interchange		
Start Year	2024	
2018 US 74 Traffic Count	16,500	NC DOT Annual Average Daily Traffic Mapping Application http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280
2018 Boardman Rd Traffic Count	908	
Truck Percentage	11%	Statewide Travel Demand Model
Auto Daily VHT Savings (2045)	322.46	Statewide Travel Demand Model
Truck Daily VHT Savings (2045)	40	Statewide Travel Demand Model
Traffic Growth Rate	0.45%	Statewide Travel Demand Model
Distance impacted by Construction (miles)	0.5	
R-5819 Old Lake Rd Overpass		
Start Year	2025	
2018 US 74 Traffic Count	15,500	NC DOT Annual Average Daily Traffic Mapping Application http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280
2018 Old Lake Rd Traffic Count	1,900	
Truck Percentage	14%	Statewide Travel Demand Model
Auto Daily VHT Savings (2045)	265	Statewide Travel Demand Model
Truck Daily VHT Savings (2045)	42	Statewide Travel Demand Model
Traffic Growth Rate	0.45%	Statewide Travel Demand Model
Distance impacted by Construction (miles)	0.5	
R-5820 Chauncey Town Interchange		
Start Year	2025	
2018 US 74 Traffic Count	15,500	NC DOT Annual Average Daily Traffic Mapping Application http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280
2018 Chauncey Town Rd Traffic Count	3,014	
Truck Percentage	13%	Statewide Travel Demand Model
Auto Daily VHT Savings (2045)	269	Statewide Travel Demand Model
Truck Daily VHT Savings (2045)	43	Statewide Travel Demand Model
Traffic Growth Rate	0.45%	Statewide Travel Demand Model
Distance impacted by Construction (miles)	0.5	
R-5751 NC 130/NC 72 Interchange		
Start Year	2026	
2018 US 74 Traffic Count	13,059	NC DOT Annual Average Daily Traffic Mapping Application http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280
2018 NC 72 Traffic Count	2,200	
Truck Percentage	11%	Statewide Travel Demand Model
Auto Daily VHT Savings (2045)	232	Statewide Travel Demand Model
Truck Daily VHT Savings (2045)	23	Statewide Travel Demand Model

Traffic Growth Rate	0.45%	Statewide Travel Demand Model
Distance impacted by Construction (miles)	0.7	
Corridor Wide Improvements		
Start Year	2025	
Entire Length (miles)	278.5	
Approx. US 74 Daily Traffic (2020)	20,000	NC DOT Annual Average Daily Traffic Mapping Application http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280
Growth Rate	0.50%	Statewide Travel Demand Model
Fiber Annual O&M	$50,000	
ITS Annual O&M	$100,000	
Resilience Features Annual O&M	$227,000	
Marshville to Wadesboro Traffic (2045)	25,402	Statewide Travel Demand Model
Truck Percentage	9%	Statewide Travel Demand Model
Environmental		
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 NO_X (average of 8a and 8b trucks)	39.0515	
Truck Emissions Rate g per hour $PM_{2.5}$ (average of 8a and 8b trucks)	1.092	
VOC Value of Emissions (2018$) per short ton	$2,100	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
NO_X Value of Emissions (2018$) per short ton	$8,600	
PM Value of Emissions (2018$) per short ton	$387,300	
Safety		
O- No injury (2018$)	$3,200	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
C - possible injury (2018$)	$63,900	
B - non-incapacitating injury (2018$)	$125,000	
A - incapacitating (2018$)	$459,100	
K - killed (2018$)	$9,600,000	

Benefits

Safety

The Project elements will result in a safer facility with the upgrades reducing the number of crashes resulting in fatalities, injuries, and property damage. The monetization of these safety benefits is 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 3.

Reduced Highway Fatalities and Crashes

Annual crash reductions were estimated using the most recent 5-year history of crashes on the facilities (2015-2019) and applying an applicable safety reduction factor. Where available, the

analysis used a North Carolina safety benefit factor (SBF); for improvements that did not have an appropriate SBF, a relevant crash reduction factor (CRF) was applied. Historical crashes and annual crash reductions for each Project component are summarized in Table 4. Safety benefits were monetized by summing the products of the KABCO value (shown in Table 3) by the number of annual crashes reduced for each Project component and are escalated throughout the 30-year analysis period in accordance with traffic growth projections.

Table 4 – Annual Crash Reduction by Project Component

KABCO Value	Shelby Bypass	R-4045	R-5797	R-5819	R-5820	R-5751	Corridor Wide[1]
2015-2019 Historical Crashes							
K	7	0	4	0	3	0	2
A	18	1	1	0	0	2	3
B	155	13	7	1	4	3	12
C	516	24	10	2	5	6	49
O	1491	63	14	1	6	18	84
SBF or CRF	SBF[2]	SBF[3]	SBF[3]	CRF[4]	SBF[3]	SBF[3]	SBF[5]
Crash Reduction	10%	40%	40%	90%	40%	40%	15%
Annual Crash Reduction							
K	0.14	0	0.32	0	0.24	0	0.06
A	0.36	0.08	0.08	0	0	0.16	0.09
B	3.1	1.04	0.56	0.18	0.32	0.24	0.36
C	10.32	1.92	0.8	0.36	0.4	0.48	1.47
O	29.82	5.04	1.12	0.18	0.48	1.44	2.52
Annual Crash Reduction Value (2018 $M)							
	$22.4	$2.6	$34.9	$0.5	$24.0	$1.3	$7.3

[1]Safety benefits calculated for the Marshville and Wadesboro areas based on signal synchronization
[2]SBF: 5A: Construct Roadway on New Location – Freeway Bypass
[3]SBF: 7: Upgrade At-Grade Intersection to Interchange
[4]CRF: 9.17: Grade Separation – No Interchange
[5]SBF: 14: Closed Loop Signal System

The total safety benefits amount to $92.9 million over the 30-year analysis period discounted at 7 percent.

Economic Vitality

Travel Time Savings

Improvements to US 74 would result in travel time savings for highway users. Travel time savings are assessed individually by project component.

Shelby Bypass

Construction of the Shelby Bypass would result in travel time savings for through traffic diverted to the Shelby Bypass and for local traffic remaining on the existing US 74 corridor.

The Shelby Bypass was designed in 5 segments; Segments A-C are already constructed or are currently under construction. The CORESI Project would construct Segments D and E to

complete the Bypass. Because other segments are already constructed, the CORESI Project cannot claim the benefits from the local traffic that is already using the Bypass. Therefore, this analysis focuses on the effects of diverting through-traffic once the entire Bypass is complete.

Based on the regional travel demand model, which assumed a speed of 65 mph on the Shelby Bypass and 45 mph on US 74, construction of the Shelby Bypass would reduce travel times for through traffic by 380 hours daily by 2045 compared to the no-build scenario. An annualization factor of 250 was applied to derive an annual time savings of 99,500 hours in 2045, which was escalated by the assumed annual traffic growth rate of 0.14 percent throughout the remainder of the 30-year analysis period. Annual time savings were reduced by 0.14 percent each year back to 2027, when benefits are to begin, to calculate the travel time savings between 2027-2045. Truck traffic accounts for 22 percent of traffic volume in the corridor and through-traffic traveling greater than 50 miles accounts for 66 percent of passenger vehicle traffic.

The diversion of through-traffic to the Shelby Bypass would result in a time savings of 2.9 minutes per trip for local traffic remaining on the existing US 74 corridor. An annualization factor of 250 was applied to the 2045 traffic estimate of 28,000 average annual daily vehicles, which was adjusted by the assumed annual traffic growth rate of 0.14 percent throughout the 30-year analysis period. The truck percentage of 22 percent was used to derive time savings for passenger vehicles and trucks, respectively.

A vehicle occupancy rate of 1.67 was applied to passenger vehicles. Applying the value of time for all purposes to passenger vehicles ($16.60 per hour), the value of time for long distance intercity for all purposes ($21.98 per hour), and the value of time for commercial trucks ($29.50 per hour) results in passenger time savings and truck time savings, respectively.

Travel time savings for through traffic following completion of the Shelby Bypass results in $25.6 million in benefits over the 30-year analysis period, discounted at 7 percent. Travel time savings for local traffic resulting from the construction of the Shelby Bypass amounts to $104.4 million in benefits over the 30-year analysis period. Total travel time savings following construction of the Shelby Bypass portion of the Project over the 30-year analysis period amounts to $130.0 million discounted at 7 percent.

R-4045

Upgrading an at-grade intersection to a new interchange at R-4045 will result in travel time savings. Based on the regional travel demand model, the new interchange at Lattimore Road (R-4045) will result in a daily travel time savings of 160 hours in 2045 compared to the no-build scenario. An annualization factor of 250 was applied to estimate travel time savings for 2045, which was adjusted by the assumed annual traffic growth rate of 0.14 percent throughout the 30-year analysis period. A truck rate of 22 percent was applied to estimate the share of truck traffic compared to passenger vehicles, and an occupancy rate of 1.67 was applied to passenger vehicles.

Applying the value of time for all purposes to passenger vehicles ($16.60 per hour) and the value of time for commercial trucks ($ 29.50 per hour) results in passenger time savings and truck time savings, respectively. Total travel time savings associated with the R-4045 portion of the Project over the 30-year analysis period amounts to $9.0 million discounted at 7 percent.

R-5797

Upgrading an at-grade intersection with a new interchange at R-5797 will result in travel time savings. Based on the statewide travel demand model, the new interchange at Boardman Road (R-5797) will result in a daily travel time savings of 320 hours for passenger vehicles and 40 hours for trucks by 2045 compared to the no-build scenario. An annualization factor of 250 was applied to estimate total travel time savings for 2045, which was adjusted by the assumed annual traffic growth rate of 0.45 percent throughout the 30-year analysis period. An occupancy rate of 1.67 was applied to passenger vehicles.

Applying the value of time for all purposes to passenger vehicles ($16.60 per hour) and the value of time for commercial trucks ($ 29.50 per hour) results in passenger time savings and truck time savings, respectively. Total travel time savings associated with the R-5797 portion of the Project over the 30-year analysis period amounts to $24.4 million discounted at 7 percent.

R-5819

Upgrading an at-grade intersection to an overpass will result in travel time savings at R-5819. Based on the statewide travel demand model, the new overpass at R-5819 will allow traffic on both US 74 and Old Lake Road to increase their speeds, result in a daily travel time savings of 150 hours for passenger vehicles and 20 hours for trucks by 2045 compared to the no-build scenario. This includes the slight increase in travel time for vehicles currently entering or exiting US 74 at Old Lake Road, which will have to use an alternate intersection/ interchange. An annualization factor of 250 was applied to estimate travel time savings for 2045, which was adjusted by the assumed annual traffic growth rate of 0.45 percent throughout the 30-year analysis period. An occupancy rate of 1.67 was applied to passenger vehicles.

Applying the value of time for all purposes to passenger vehicles ($16.60 per hour) and the value of time for commercial trucks ($ 29.50 per hour) results in passenger time savings and truck time savings, respectively. Total travel time savings associated with the R-5819 portion of the Project over the 30-year analysis period amounts to $11.0 million discounted at 7 percent.

R-5820

Upgrading an at-grade intersection to a new interchange at R-5820 will result in travel time savings. Based on the statewide travel demand model, the new interchange at Chauncey Town Road (R-5820) will result in a daily travel time savings of 170 hours for passenger vehicles and 30 hours for trucks by 2045 compared to the no-build scenario. An annualization factor of 250 was applied to estimate travel time savings for 2045, which was adjusted by the assumed annual traffic growth rate of 0.45 percent throughout the 30-year analysis period. An occupancy rate of 1.67 was applied to passenger vehicles.

Applying the value of time for all purposes to passenger vehicles ($16.60 per hour) and the value of time for commercial trucks ($29.50 per hour) results in passenger time savings and truck time savings, respectively. Total travel time savings associated with the R-5820 portion of the Project over the 30-year analysis period amounts to $12.3 million discounted at 7 percent.

R-5751

Upgrading an at-grade intersection to a new interchange at R-5751 will result in an additional travel time savings. Based on the statewide travel demand model, a new interchange at NC72/NC130 (R-5751) will result in a daily travel time savings of 230 hours for passenger vehicles and 20 hours for trucks by 2045 compared to the no-build scenario. An annualization factor of 250 was applied to estimate travel time savings for 2045, which was adjusted by the assumed annual traffic growth rate of 0.45 percent throughout the 30-year analysis period. An occupancy rate of 1.67 was applied to passenger vehicles.

Applying the value of time for all purposes to passenger vehicles ($16.60 per hour) and the value of time for commercial trucks ($29.50 per hour) results in passenger time savings and truck time savings, respectively. Total travel time savings associated with the R-5751 portion of the Project over the 30-year analysis period amounts to $15.1 million discounted at 7 percent.

Corridor Wide Improvements

Installing ITS signal coordination between Charlotte and Rockingham will result in additional travel time savings.

The statewide travel demand model was used to calculate daily travel time savings of the installation of ITS signal coordination in Marshville and Wadesboro; this improvement would

result in a total daily time savings of 2,450 hours in 2045 compared to the no-build scenario. An annualization factor of 250 was applied to estimate travel time savings for 2045, which was escalated by the assumed annual traffic growth rate of 0.45 percent throughout the remainder of the 30-year analysis period. A truck share of 9 percent was applied to the time savings and an occupancy rate of 1.67 was applied to passenger vehicles to monetize time savings associated with the installation of ITS signal coordination.

Applying the value of time for all purposes to passenger vehicles ($16.60 per hour) and the value of time for commercial trucks ($29.50 per hour) results in passenger time savings and truck time savings, respectively. Total travel time savings associated with the installation of ITS signal coordination between Charlotte and Rockingham amounts to $143.5 million over the 30-year analysis period discounted at 7 percent.

Vehicle Operating Cost Savings

Travel time savings and mileage differences from the Project would also result in vehicle operating cost changes.

The 2020 BCA Guidance for Discretionary Grant Programs provides operating costs for passenger vehicles on a per-mile basis. The American Transportation Research Institute (ATRI) provides operating costs for trucks both per-mile and per-hour. Therefore, project components that affect mileage impact both passenger vehicles and trucks, whereas project components that affect travel time only impact truck operating costs.

The increased vehicle miles traveled on the Shelby Bypass will result in an increase in operating costs for vehicles diverted from the existing US 74 corridor. Conversely, travel time savings incurred by truck traffic will result in operating cost savings.

Through traffic on the Shelby Bypass would travel an additional 1.8 miles per trip. Operating costs of $0.39 per mile were used for passenger vehicles and $1.17 per mile were used for trucks. An annualization factor of 250 was applied to the 2045 vehicle traffic count, which was adjusted by the assumed annual traffic growth rate of 0.14 percent throughout the 30-year analysis period.

Due to the additional mileage, vehicles traveling through the Shelby Bypass would incur an additional $23.7 million in operating costs over the 30-year analysis period, discounted at 7 percent. Traffic remaining on US 74 would not incur additional operating costs because those vehicles' mileage would not change.

All other project components result in travel time savings and no change in mileage. The time savings for truck traffic (local and through) that result from the construction of the Shelby Bypass, R-4045, R-5797, R-5819, R-5820, R-5751, and the ITS improvements, as described under Travel Time Savings, result in truck operating cost savings. The hourly truck operating cost savings of $46.16 from ATRI was applied to the time savings to derive truck operating cost savings. Overall, the project will decrease vehicle operating costs by $50.3 million over the 30-year analysis period discounted at 7 percent.

Work Zone Impacts

Existing US 74 and cross-street traffic will be impacted while the Project improvements are under construction. It is assumed that traffic will be slowed by 20 mph in the affected areas for the duration of Project construction. This will impact travel time for both passenger vehicles and trucks and operating costs for trucks. Using the travel time and operating cost values stated in the prior sections of this memorandum, work zone impacts are shown in Table 5.

Table 5 – Work Zone Impacts

	Shelby Bypass	R-4045	R-5797	R-5819	R-5820	R-5751
2020 US 74 Traffic	38,611	20,000	16,500	15,500	15,500	13,059
2020 Cross-Street Traffic	N/A	950	908	1,900	3,014	2,200
Percent Trucks	23%	22%	11%	14%	13%	11%
Annual Growth Rate	0.14%	0.14%	0.45%	0.45%	0.45%	0.45%
Existing Speed	45	55	55	55	55	55
Construction Speed	25	35	35	35	35	35
Impacted Area (Miles)	3	0.5	0.5	0.5	0.5	0.7
Work Zone Impact ($M Discounted at 7%)	$27.8	$3.1	$1.3	$2.0	$2.0	$2.2

Corridor-wide improvements are not anticipated to have work zone impacts. Total CORESI work zone impacts are $38.3 million, discounted at 7 percent.

Autonomous Vehicles Benefit

The installation of fiber optic cable along the corridors would provide the groundwork for the future of autonomous vehicles. Fiber optic cable would be constructed by 2026 along the US 74 corridor. As smart vehicles are becoming more affordable, drivers will increasingly be driving autonomous vehicles. Preparing the transportation infrastructure for these new vehicle capabilities allows for the continued safe and efficient movement of goods and people along corridors.

This analysis considers a slow ramp-up of the use of autonomous vehicles on the corridors based on the paper “Autonomous Cars Self-Driving the New Auto Industry Paradigm,” by Morgan Stanley.[3]

The paper estimates costs to drivers for vehicle upgrades to be about $10,000 in the near-term and $2,000 for the long-term. 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, through 2034. Because each year an increasing proportion of vehicles are autonomous-equipped, the costs of the net new vehicles adopted are added. For the next 20 years, the net new vehicles are multiplied by the assumed cost of $2,000 cost per vehicle.

An adoption curve for the equipped-vehicles was assumed to be 1.0 percent in 2022, increasing to 100 percent by 2055. 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 area. This analysis assumes a low scenario of realizing benefits, where autonomous vehicles and their associated benefits slowly “ramp up” in use in the corridor from 1 percent in 2026 to 64 percent by the end of the analysis period. The cost and benefits adoption curves are shown in Table 6.

[3] "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 6 – Autonomous Vehicles Adoption Curves for Costs and Benefits

Year	Costs: Adoption Curve	Benefits: Low Ramp-up
2026	11.5%	1%
2027	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	77.7%	38%
2045	81.8%	41%
2046	85.9%	43%
2047	87.0%	45%
2048	90.1%	47%
2049	92.7%	50%
2050	95.3%	52%
2051	97.9%	54%
2052	99.0%	57%
2053	99.0%	59%
2054	99.0%	61%
2055	100.0%	64%

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.

Based on the AADT in the corridor in 2020 (about 20,000), the share of national benefits estimated for autonomous vehicles was reduced by a ratio of 20,000 vehicles compared to the national 250 million cars on the road. For US 74, this represents 0.008 percent of the national benefit, or $115 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 benefits for US 74 amounts to $133.0 million discounted at 7 percent.

Residual Benefits

The Project would have residual value after the end of the 30-year analysis period because the useful life of the Project elements is longer than 30 years. Highways and streets and sewer systems have a useful life of 60 years,[4] while fiber optic cable has a useful life of 40 years.[5] Land value associated with the ROW does not depreciate. The analysis assumed a straight-line depreciation for all assets besides ROW; the value of ROW was added to the total value of the other assets and discounted from the final year of the analysis period. The total residual value for the Project discounted at 7 percent is $9.4 million. Residual benefits per Project element are summarized in Table 7.

Table 7 – Residual Benefits by Project Element (in 2018 $M), Discounted at 7 percent

Shelby Bypass	R-4045	R-5797	R-5819	R-5820	R-5751	Corridor Wide
$6.3	$0.7	$1.2	$0.6	$1.1	$0.8	$0.8

O&M Costs

The Project requires annual and periodic operating and maintenance (O&M) costs to keep the road, interchanges, and ITS elements in a state of good repair. O&M includes renewal and replacement costs, beginning in 2027.

Shelby Bypass

Construction of the Shelby Bypass would result in an annual O&M cost of $0.7 million. The total O&M costs associated with the construction of the Shelby Bypass amount to $5.9 million over the 30-year analysis period, discounted at 7 percent.

R-4045

Construction of the interchange upgrades at R-4045 would increase annual O&M costs by $8,000. The total O&M costs associated with the construction of the interchange upgrades at R-4045 amount to $0.1 million over the 30-year analysis period, discounted at 7 percent.

R-5797

Construction of the interchange upgrades at R-5797 would increase annual O&M costs by $1,000. The total O&M costs associated with the construction of the interchange upgrades at R-5797 amount to $10,000 over the 30-year analysis period, discounted at 7 percent.

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[4] 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

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

R-5819

Construction of the interchange upgrades at R-5819 would increase annual O&M costs by $1,000. The total O&M costs associated with the construction of the interchange upgrades at R-5819 amount to $9,000 over the 30-year analysis period, discounted at 7 percent.

R-5820

Construction of the interchange upgrades at R-5820 would increase annual O&M costs by $2,000. The total O&M costs associated with the construction of the interchange upgrades at R-5820 amount to $9,000 over the 30-year analysis period, discounted at 7 percent.

R-5751

Construction of the interchange upgrades at R-5751 would increase annual O&M costs by $1,000. The total O&M costs associated with the construction of the interchange upgrades at R-5751 amount to $18,000 over the 30-year analysis period, discounted at 7 percent.

Corridor Wide Improvements

Construction of the corridor wide improvements would increase annual O&M costs by $0.4 million. The total O&M costs associated with the construction of the corridor wide improvements amount to $3.3 million over the 30-year analysis period, discounted at 7 percent.

Environmental

Reduced Emissions

The truck travel time savings associated with the Project would result in emissions reductions. To be conservative, passenger vehicle emissions were not monetized in the analysis.

Shelby Bypass

Construction of the Shelby Bypass would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3.[6] The tons of reduced emissions were monetized using the recommended value of emissions as shown in Table 3. In total, the Shelby Bypass results in truck emissions savings of $0.6 million, discounted at 7 percent.

R-4045

The interchange upgrades at R-4045 would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3. The tons of reduced VOC, NO_X, and $PM_{2.5}$ emissions were monetized using the recommended value of emissions as shown in Table 3. In total, the interchange upgrades at R-4045 would result in truck emissions savings of $49,000, discounted at 7 percent.

R-5797

The interchange upgrades at R-5719 would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3. The tons of reduced VOC, NO_X, and $PM_{2.5}$ emissions were monetized using the

[6] 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

recommended value of emissions as shown in Table 3. In total, the interchange upgrades at R-4045 would result in truck emissions savings of $67,000, discounted at 7 percent.

R-5819

The overpass at R-5819 would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3. The tons of reduced VOC, NO_X, and $PM_{2.5}$ emissions were monetized using the recommended value of emissions as shown in Table 3. In total, the interchange upgrades at R-5819 would result in truck emissions savings of $38,000, discounted at 7 percent.

R-5820

The interchange upgrades at R-5820 would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3. The tons of reduced VOC, NO_X, and $PM_{2.5}$ emissions were monetized using the recommended value of emissions as shown in Table 3. In total, the interchange upgrades at R-5820 would result in truck emissions savings of $40,000 discounted at 7 percent.

R-5751

The interchange upgrades at R-5751 would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3. The tons of reduced VOC, NO_X, and $PM_{2.5}$ emissions were monetized using the recommended value of emissions as shown in Table 3. In total, the interchange upgrades at R-5751 would result in truck emissions savings of $34,000, discounted at 7 percent.

Corridor Wide Improvements

The corridor wide improvements would result in travel time savings for users and therefore reduced emissions. The time savings from the travel demand model were used to estimate emissions savings. Annual volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$) savings were estimated based on rates found from the EPA and shown in Table 3. The tons of reduced VOC, NO_x, and $PM_{2.5}$ emissions were monetized using the recommended value of emissions as shown in Table 3. In total, the corridor wide improvements would result in truck emissions savings of $0.3 million, discounted at 7 percent.

Costs

Capital Costs

The capital costs for the Project include the costs for the purchase of land, utility relocation, construction, and contingency. The capital costs for each Project component are shown in Table 8.

Table 8 – Capital Costs by Project Component (in 2018 $M)

Project Component	Construction Period	Capital Cost
Shelby Bypass	2023-2026	$144.6
R-4045	2023-2026	$15.1
R-5797	2022-2023	$27.8
R-5819	2022-2024	$14.7
R-5820	2022-2024	$26.5
R-5751	2023-2025	$21.4
Corridor Wide	2020-2026	$43.5
Total	2020-2026	**$293.5**

Source: NCDOT

The capital costs are applied over an eight-year construction period, beginning in 2019 (previously incurred professional engineering (PE) and ROW) and ending in 2026. Previously incurred costs for PE and ROW acquisition are estimated at $24.1 million in 2018 dollars and were assumed to have been spent in 2019.

The Corridor Wide Improvements components of the Project include resiliency elements such as vulnerability assessments, stress testing, FIMANT, Bridgewatch, and gauges on bridges and culverts at 18 locations. The resiliency items total $2.1 million, estimated in 2018 dollars, and will be constructed over seven years from 2020-2026.

The total capital costs for the Project are $232.5 million, discounted at 7 percent.

Summary

Table 9 summarizes the discounted value of the benefits and costs described in this memorandum for the Project. Taken in total and using a 7 percent discount rate, the Project provides $586.3 million of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 2.5, a solid return on these critical investments. The net benefits total $353.8 million. In addition, all of the project elements have greater benefits than costs, demonstrating they are cost-effective on their own.

Table 9 – BCA Summary

7% Discount Rate, $Millions	US 74 CORESI Project							
Benefit	**Shelby Bypass**	**R-4045**	**R-5797**	**R-5819**	**R-5820**	**R-5751**	**Corridor Wide Improvements**	**Total**
Safety								
Reduced Accidents	$22.4	$2.6	$34.9	$0.5	$24.0	$1.3	$7.3	$92.9
Economic Vitality								
Travel Time Savings	$130.0	$9.0	$24.4	$11.0	$12.3	$15.1	$143.5	$345.3
Vehicle Operating Cost Savings	$13.0	$3.2	$4.5	$2.5	$2.7	$2.3	$22.2	$50.3
Work Zone Impacts	-$27.8	-$3.1	-$1.3	-$2.0	-$2.0	-$2.2		-$38.3
Autonomous Vehicles							$133.0	$133.0
Residual	$6.3	$0.7	$1.2	$0.6	$1.1	$0.8	$0.8	$11.3
O&M	-$5.9	-$0.1	$0.0	$0.0	$0.0	$0.0	-$3.3	-$9.3
Environmental								
Reduced Emissions	$0.6	$0.0	$0.1	$0.0	$0.0	$0.0	$0.3	$1.1
Total Benefits	**$138.7**	**$12.3**	**$63.6**	**$12.7**	**$38.0**	**$17.3**	**$303.7**	**586.3**
Costs								
First Costs	$117.4	$11.2	$22.9	$11.2	$21.4	$15.2	$33.4	$232.5
Total Costs	**$117.4**	**$11.2**	**$22.9**	**$11.2**	**$21.4**	**$15.2**	**$33.4**	**$232.5**
Benefit Cost Analysis								
Net Present Value	**$21.3**	**$1.2**	**$40.8**	**$1.4**	**$16.7**	**$2.1**	**$270.3**	**$353.8**
Benefit Cost Ratio	**1.2**	**1.1**	**2.8**	**1.1**	**1.8**	**1.1**	**9.1**	**2.5**

List of Supporting Information

US74_CORESI_BCA_FINAL.xlsx (Excel spreadsheet with BCA calculations by benefit type and summary)

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

Morgan Stanley, 2013, "Autonomous Cars Self-Driving the New Auto Industry Paradigm", 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-ARADIGM.pdf

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

U.S. DOT, 2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, https://cms8.dot.gov/sites/dot.gov/files/2020-01/benefit-cost-analysis-guidance-2020_0.pdf

U.S. DOT, 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