

Technical Memorandum:

Benefit-Cost Analysis for the I-85/I-40 Foundations for Automated and Safer Transportation Project

Date: July 15, 2019

Subject: Benefit-Cost Analysis for the I-85/I-40 Foundations for Automated and Safer Transportation Benefit-Cost Analysis

Project Description

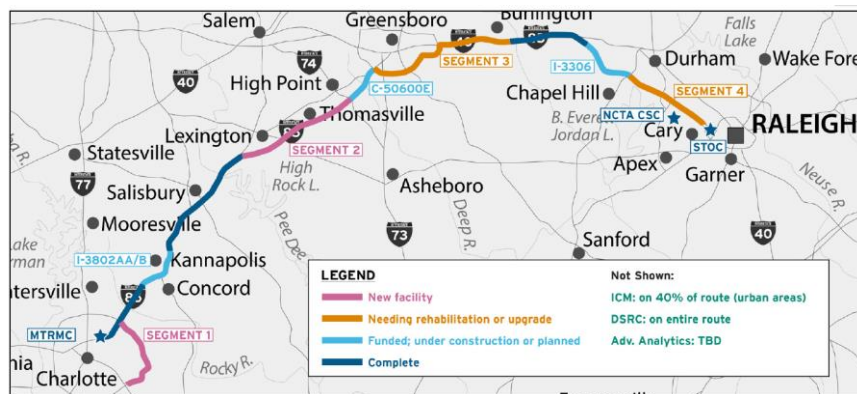
The NCDOT I-85/I-40 Foundations for Automated and Safer Transportation Project will improve safety, increase reliability and add communications infrastructure to one of the most traveled corridors in the state. The Project proposes to accomplish these goals with a suite of transportation technology improvements.

The Project will complete the NCDOT fiber-optic trunk line connection between the state's two largest Transportation Management Centers. This will create opportunities to lease NCDOT communications infrastructure to the private sector. New wireless communication infrastructure will facilitate connected and automated vehicle technology. Two new safety systems at pilot locations will deter wrong-way driver and curve departure crashes. The Project will add technology to interstate alternate routes and will aid in integrated corridor management. Finally, the project proposes to deploy state-of-the-art advanced analytics to detect dangerous behavior and conditions on the interstate.

By deploying these systems, and enhancing existing systems, NCDOT will continue to be a leader in using technology to manage congestion, improve driver safety, stimulate economy growth, and work proactively with the commercial sector.

A map of the Project is shown in **Exhibit 1**.

Exhibit 1 – Project Location



Introduction

This technical memorandum estimates the long-term benefits associated with the Project. The long-term benefits presented relate to two of the goals identified in the BUILD 2019 Notice of Funding Opportunity (NOFO)¹: Safety and Economic Competitiveness. The final section discounts the stream of anticipated benefits and costs and calculates the Benefit-Cost Ratios for the Project at 7 percent and 3 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, reducing the likelihood for accidents, providing new/enhanced fiber internet connections, 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 estimates the value of the long-term benefits generated by the investment. The benefits of the capital investment have been estimated over a 20-year analysis horizon.

The Project's construction would be completed in mid-2023, and a benefits period of 2023-2042 was used.

Benefits are estimated in accordance with guidance provided by U.S. Department of Transportation (U.S. DOT) for benefit-cost analysis. If no U.S. DOT guidance was available for the estimate, the Project team consulted industry research 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 2019 dollars. 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 **Exhibit 2**.

Exhibit 2 - BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2017 TIGER BCA Resource Guide
Discount Rate	3%	2017 TIGER BCA Resource Guide
Auto Occupancy	1.39	2017 TIGER BCA Resource Guide, FHWA Statistics 2015, Table VM1
Annualization Factor	280	Assumption
Speed Limit on I-85	67.5	Actually Average of 65mph and 70mph
Annual O&M Fiber	\$50,000	INFRA 2017 value
Annual O&M ITS	\$200,000	INFRA 2017 value was \$100,000; assumed a higher value to be conservative
40% of Average 2016 AADT in the most urban counties on the route	52,400	https://connect.ncdot.gov/resources/State-Mapping/Documents/NCDOT2016InterstateFreewayReport.pdf
Truck share I-85	11.6%	Statewide Travel Demand Model
I-85 annual AADT growth	3.4%	NCDOT, values for the entire corridor ranged from 3.4% to 4.2%; used lower figure
Economic Vitality		
Value of Personal Time, 2016\$	\$13.60	2017 TIGER BCA Resource Guide
Value of Business Time, 2016\$	\$25.40	2017 TIGER BCA Resource Guide
Value of Time All Purposes, 2016\$	\$14.10	2017 TIGER BCA Resource Guide
Value of Time Truck, 2016\$	\$27.20	2017 TIGER BCA Resource Guide
Value of Personal Time, 2017\$	\$13.85	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Value of Business Time, 2017\$	\$25.87	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Value of Time All Purposes, 2017\$	\$14.36	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Value of Time Truck, 2017\$	\$27.70	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Average Trip Length on I-85	30	Assumption; reduced from 45 min. value in INFRA 2017 application
Reliability savings	2%	Assumption based on range of results found https://ntl.bts.gov/lib/54000/54300/54346/ICM_Modeling_Results_Report_FHWA-JPO-12-037_.pdf
NCTA Fiber Savings (Per Month)	\$2,250	NCTA Toll Integrator (TransCore)
DOT Fiber Savings (Per Month)	\$1,000	NCDOT IT
Safety		
AIS 0 (2016\$) per vehicle	\$4,252	2017 TIGER BCA Resource Guide
AIS 1 (2016\$)	\$28,800	2017 TIGER BCA Resource Guide
AIS 2(2016\$)	\$451,200	2017 TIGER BCA Resource Guide
AIS 3(2016\$)	\$1,008,000	2017 TIGER BCA Resource Guide
AIS 4(2016\$)	\$2,553,600	2017 TIGER BCA Resource Guide
AIS 5(2016\$)	\$5,692,800	2017 TIGER BCA Resource Guide
AIS 6(2016\$)	\$9,600,000	2017 TIGER BCA Resource Guide
AIS 0 (2017\$) per vehicle	\$4,330	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
AIS 1 (2017\$)	\$29,329	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
AIS 2 (2017\$)	\$459,483	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
AIS 3 (2017\$)	\$1,026,505	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
AIS 4 (2017\$)	\$2,600,480	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
AIS 5 (2017\$)	\$5,797,311	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
AIS 6 (2017\$)	\$9,776,242	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
C - possible injury (2016\$)	\$63,900	2017 TIGER BCA Resource Guide
B - non-incapacitating injury (2016\$)	\$125,000	2017 TIGER BCA Resource Guide
A - incapacitating (2016\$)	\$459,100	2017 TIGER BCA Resource Guide
K - killed (2016\$)	\$9,600,000	2017 TIGER BCA Resource Guide
C - possible injury (2017\$)	\$65,073	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
B - non-incapacitating injury (2017\$)	\$127,295	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
A - incapacitating (2017\$)	\$467,528	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
K - killed (2017\$)	\$9,776,242	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator

Benefits

Safety

Reduced Highway Fatalities and Crashes

This crash reduction factors for **Exhibit 3** were converted to the Maximum Abbreviated Injury Score (MAIS) crash types in order to apply U.S. DOT Guidance on the value of avoided crashes. The conversion is based on the National Highway Safety and Traffic Administration (NHTSA) KABCO- AIS Conversion Table (July 2011) for Injury (severity unknown), and No Injury crashes. KABCO refers to the letters used to designate five levels of crash severity used by police at a crash scene; AIS refers to the Abbreviated Injury Scale used by hospitals. These factors provide the probability that an injury will range from critical to minor to more accurately capture the total number of different types of injuries associated with the VMT avoided on less safe facilities.

Estimating the distribution of expected injury types is important (see **Figure 3**) because each type of injury has a different associated economic cost.

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. **Exhibit 2** provides the estimated cost of different types of crashes.

Based on the value of accidents avoided, the value of safety incidents avoided due to the deployment of the safety systems is estimated.

Exhibit 3 – Project Crash Reduction Factors

Location	Crash Reduction (Crashes/Year)				
	Fatal	Incapacitating Injury (A)	Non-incapacitating Injury (B)	Possible Injury (C)	PDO
WWD and DCWS	0.1	0.15	0.4	0.65	6.9

Source: HNTB safety analysis.

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 as found in **Exhibit 2**.

The total benefit based on reduction in fatalities and crashes on the project is \$8.8 million, discounted at 7 percent.

Economic Competitiveness

Fiber Benefits

The Project utilizes transportation infrastructure investment to accomplish more than just transportation. There is a digital divide between rural and urban areas in terms of access to the high-speed broadband and communications capability needed to run modern applications.

Exhibit 4 highlights the geographic pattern of high-speed connectivity in the state and the large gaps in service in the Project area. This lack of access hinders economic development in small communities, limits agricultural access to applications that use big data to monitor and assess micro climate and yield data over large areas, and restricts educational opportunities. NCDOT will be working with its State Agency partners to utilize this new communications backbone to deliver these types of benefits.

Exhibit 4 - Broadband Availability at 25 MBPS Download Speeds



Source: Connecting North Carolina, State Broadband Plan, 2016

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

The Project will install enhanced enterprise-level fiber infrastructure along the most rural section of the I-85 corridor, allowing for faster internet access for central North Carolina, among other connectivity improvements. This benefit is quantified using a willingness to pay (WTP) methodology. As found in the literature,² the value of an increase in broadband internet up to at least 4 MBPS is worth \$10.37. This is assumed to be per household and is conservative as a typical internet speed is about 25 MBPS and therefore would be valued higher. It is assumed that 50% households within the selected counties, as found from Census 2010, would be WTP once per year for the improved internet connection. The county households increase annually based on population growth from the NC OSBM.³

The total fiber benefit for the project amounts to \$7.4 million discounted at 7 percent.

In addition, the prospect of adding 5G cellular network has created the incentive for the private sector to upgrade their size and the reach of their current LTE fiber networks, even in urban areas. The fiber infrastructure will create partnership opportunities un-related to bring better internet to rural areas. This is a quantitative benefit to the project.

Autonomous Vehicles Benefit

The installation of fiber and Dedicated Short Range Communications (DSRC) mini-cell towers along the corridor would provide the groundwork for the future of Connected and Autonomous Vehicles (CAV). 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.

Due to uncertainties over the adoption curve of CAV technology, and the quantitative impact of the deployment on the corridor, this is deemed to be a quantitative benefit to the project.

Reliability Savings from Integrated Corridor Management

Integrated Corridor Management (ICM) will allow the corridor to be centrally managed and therefore will benefit users from increased efficiencies. One such efficiency is an increase in reliability, or a reduced buffer time on trips. Because of unreliable congestion in the No Build, users may add extra time to trips; with the Build, however, that extra time can be reduced. As estimated by the FHWA for pilot studies in San Diego, Dallas, and Minneapolis, an improvement in travel time reliability was found to range from 3.3 percent to 10.6 percent; 2 percent was conservatively used in this analysis.⁴ This reduction in travel time variance is quantified as travel time savings.

ICM is proposed to be deployed on the most urban 60 miles of the corridor. Based on the average traffic volume in the Project area of the most urban 60 miles of the corridor⁵, the average trip length of 30 minutes, and an average speed limit of 67.5 mph, an estimated baseline travel time can be calculated. Applying the 4 percent reliability improvement to the average trip time results in the time savings in the corridor. Traffic is expected to increase by at least 3.7 percent per year.⁶ Applying the truck share and the value of time for truckers as found in **Exhibit 2** results in the truck time savings. The remaining traffic was multiplied by the auto occupancy rate and the value of auto time, as found in **Exhibit 2**.

The total reliability savings from ICM for the project amounts to \$76.1 million discounted at 7 percent.

NCDOT / NCTA Fiber Savings

Currently, NCDOT's Regional Transportation Management Centers (RTMCs) have very constrained connectivity to one another due the lack of fiber connection between them. NCDOT IT currently maintains expensive leased facilities for this purpose, and far fewer video streams can be viewed over these connections than desired. The completion of this link, including new facilities and upgrades to existing infrastructure, will eliminate this problem and reduce dependence on the leased lines. The value of this monthly savings is estimated by NCDOT IT at \$1000.

The NC Turnpike Authority (NCTA), which currently has toll roads in the Raleigh and Charlotte metro areas, must rely on expensive leased line facilities to move secure toll transactions from the Monroe Expressway roadside host located in the Metrolina RTMC in Charlotte, to the NCTA customer service center in Morrisville. The portion of this project on I-485 that will connect the Expressway to the fiber-optic backbone will allow NCTA's toll integrator to significantly reduce their reliance and cost on the leased lines, which in turn will reduce NCTA's operating costs. The value of this monthly savings is estimated by NCTA's toll integrator at \$2250.

The total benefit for the project amounts to \$300,000 discounted at 7 percent.

Costs

Capital Costs

The capital costs for the Project include the costs for completion of the fiber-optic backbone and deployment of a suite of ITS improvements. The costs of the project elements are shown in **Exhibit 5**.

Exhibit 5 – Construction Costs, 2019\$

Description	Committed State	BUILD	Total
Fiber-Optic Trunkline	\$1.334M	\$8M	\$9.334M
DSRC	\$2.880M	\$0	\$2.880M
Integrated Corridor Management	\$7.040M	\$0	\$7.040M
Wrong-Way Driver Detection and Notification Systems	\$1.370M	\$0	\$1.370M
Dynamic Curve Warning Systems	\$1.625M	\$0	\$1.625M
Advanced Analytics	\$750K	\$0	\$750K
TOTALS:	\$15.0M	\$8M	\$23.0M

The capital costs are applied over a two-year construction period, beginning in late 2021 and ending in mid-2023. **The capital costs for the project discounted at 7 percent total to \$16.07 million.**

Operating and Maintenance Costs

ITS and fiber are assumed to require minimal maintenance annually, estimated at \$200,000 and \$50,000 per year, respectively.

The total O&M costs over the analysis period and discounted at 7 percent is \$1.3 million.

Summary

Exhibit 6 summarizes the discounted value of the benefits discussed in this memorandum for the total Project. Taken in total and using a 7 percent discount rate, the Project provides \$93.1 million dollars of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 5.70, a solid return on this investment. The net present value totals \$75.3 million.

Exhibit 6 – Total Project Benefit-Cost Analysis (2023-2042 in 2019 \$M)

	Values stated in 2019 \$M	
	Discounted at 7%	Discounted at 3%
Costs		
Capital Costs	\$16.0	\$19.6
Total Costs	\$16.0	\$19.6
Benefits		
Safety		
Reduced Highway Fatalities and Crashes	\$8.8	\$15.0
Sub-Total Safety Benefits	\$8.8	\$15.0
Economic Competitiveness		
Fiber 3rd Party Leasing Benefits	\$7.4	\$12.9
Reliability Savings from ICM	\$76.1	\$133.5
NCDOT / NCTA Fiber Savings	\$0.3	\$0.5
Sub-Total Economic Competitiveness	\$83.8	\$146.9
O&M Costs	-\$1.3	-\$2.8
Net O&M	-\$1.3	-\$2.8
Total Benefits	\$93.1	\$159.1
BC Ratio	5.70	8.10
Net Present value	\$75.3	\$139.5

End Notes:

¹ See BUILD 2019 Notice of Funding Opportunity, <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/build/114796/fy-2019-nofo-final-signed.pdf>

² Peterson, Richard, "Paying for Speed: Measuring Willingness to Pay in U.S. Broadband Markets," University of Colorado, October 17, 2017, <https://www.colorado.edu/economics/gradplacement/PetersonJMP.pdf>

³ NC Management and Budget, https://files.nc.gov/ncosbm/demog/countygrowth_cert_2016.html

⁴ Integrated Corridor Management Modeling Results Report: Dallas, Minneapolis, and San Diego, https://ntl.bts.gov/lib/54000/54300/54346/ICM_Modeling_Results_Report_FHWA-JPO-12-037_.pdf

⁵ NCDOT Transportation Planning Branch, 2016 Freeway AADT Volumes, <https://connect.ncdot.gov/resources/State-Mapping/Documents/NCDOT2016InterstateFreewayReport.pdf>

⁶ NCDOT Traffic Survey Annual Average Daily Traffic excel report – see Supplemental Materials