

Technical Memorandum:

Benefit-Cost Analysis for the I-85/I-40/NC-540 Foundations for Automated and Safer Transportation Project

Date: May 18, 2020

Subject: Benefit-Cost Analysis for the I-85/I-40/NC-540 Foundations for Automated and Safer Transportation Benefit-Cost Analysis

Project Description

The North Carolina Department of Transportation (NCDOT) I-85/I-40/NC-540 Foundations for Automated and Safer Transportation Project will improve safety, increase reliability and by adding communications infrastructure and safety systems to one of the most traveled corridors in North Carolina. The Project proposes to accomplish these goals with the suite of transportation technology improvements described in the application narrative.

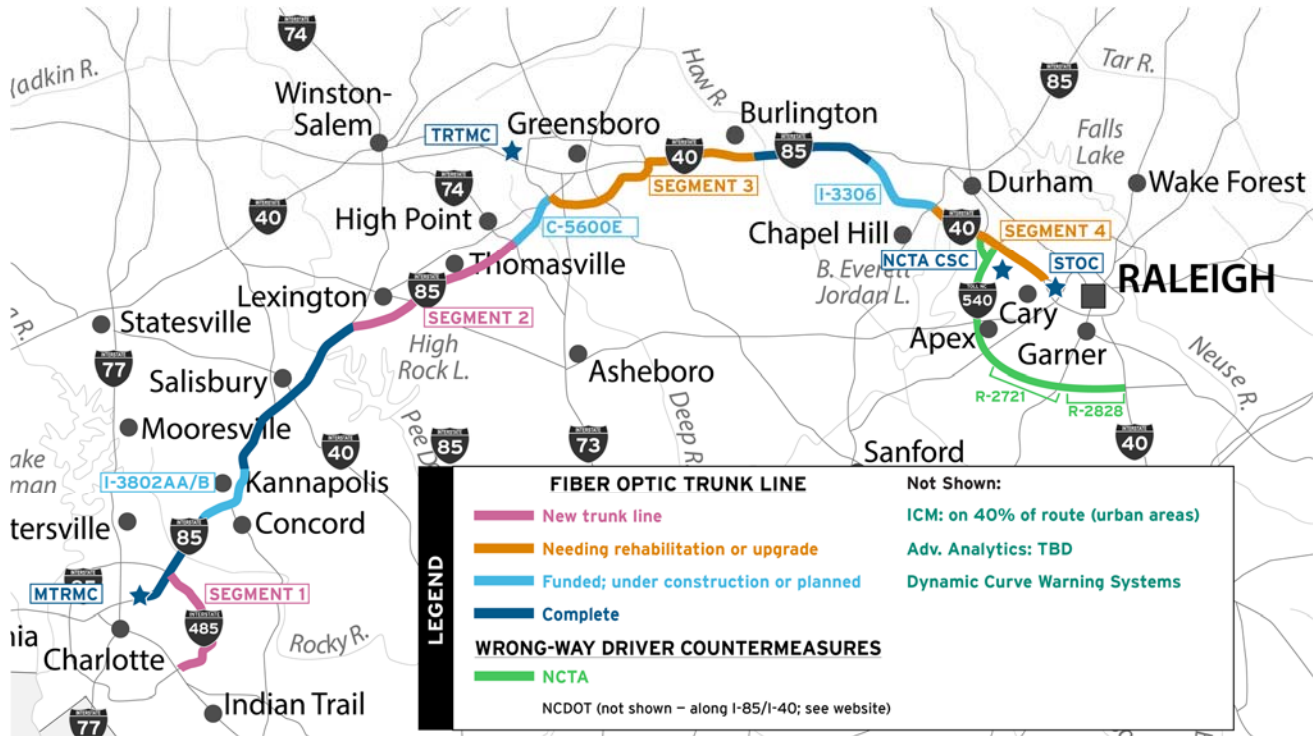
The Project will complete the NCDOT fiber-optic trunk line connection between the state's two largest Transportation Management Centers (TMCs) serving the Raleigh and Charlotte areas. This will result in cost savings by eliminating reliance on leased-line services and will also create opportunities to link local traffic signal systems to the statewide traffic management network. In addition, the completed trunk line will create opportunities to lease NCDOT communications infrastructure to the private sector. The new wireless communication infrastructure will facilitate connected and automated vehicle technology.

The Project will add technology to interstate alternate routes and will aid in integrated corridor management. Two new safety systems at 15 pilot locations will deter wrong-way driver and curve departure crashes at selected sites along I-85/I-40. The wrong-way driver countermeasures will also be placed at all off-ramps (29 in all) along the North Carolina Turnpike Authority's (NCTA's) Triangle Expressway, a heavily travelled highway linking two major metropolitan areas. Finally, the project proposes to deploy state-of-the-art advanced analytics to detect dangerous behavior and conditions on the project corridor.

By deploying these systems, and enhancing existing systems, NCDOT and NCTA will continue to be leaders 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 2020 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.

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 project. The benefits of the capital investment have been estimated over a 20-year analysis horizon.

Years of Analysis

The Project's construction would be completed in mid-2024. A benefits period of 2024-2043 was used.

Methodology

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 2020 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 Benefit/Cost Analysis (BCA) workbook (see Inputs tab in the file A01_BCA_NCDOT_I-85_I-40_NC-540_FAST_BUILD_2020.xlsx) as well as in Exhibit 2.

Exhibit 2 - BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Rate	3%	2017 TIGER BCA Resource Guide
Dollar Year	2020	
Analysis Period (years)	20	Fiber can reasonably be expected to last 20 years
Auto Occupancy	1.39	2017 TIGER BCA Resource Guide, FHWA Statistics 2015, Table VM1
Annualization Factor	250	Assumption
Speed Limit on I-85	67.5	Actual Average of 65mph and 70mph
Annual O&M Fiber	\$120,000	USDOT ITS JPO Cost Database: \$2800/mile * 42 miles of new fiber
Annual O&M ITS	\$200,000	INFRA 2017 value was \$100,000; assumed a higher value to be conservative
Annual O&M DCWS	\$37,500	Assumed to be no less than for WWD site
Annual O&M WWD - I-85/I-40	\$75,000	UCF/CFX Study gave O&M per site as \$6585/year; assume \$7500/year
Annual O&M WWD - Toll NC 540	\$217,500	UCF/CFX Study gave O&M per site as \$6585/year; assume \$7500/year
40% of Average 2016 AADT in the most urban counties on the route	40,000	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	\$15.20	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Value of Business Time	\$27.10	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Value of Time All Purposes	\$16.60	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Value of Time Truck	\$29.50	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Value of Personal Time	\$15.48	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Value of Business Time	\$27.60	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Value of Time All Purposes	\$16.90	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Value of Time Truck	\$30.04	2017 TIGER BCA Resource Guide, Adjusted by GDP Deflator
Average Trip Length on I-85	20	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) X 3 projects
DOT Fiber Savings (Per Month)	\$1,000	NCDOT IT
Safety		
O - No injury (2018\$)	\$3,200	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
C - possible injury (2018\$)	\$63,900	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
B - non-incapacitating injury (2018\$)	\$125,000	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
A - incapacitating (2018\$)	\$459,100	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
K - killed (2018\$)	\$9,600,000	2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs

Benefits

Safety

The project's quantitative safety benefits derive from the expectation of reduced crashes at the wrong-way driver countermeasure sites.

Due to the very small number of deployments for the Dynamic Curve Warning System, the reduced crash rate at the five sites is deemed to be a qualitative benefit to the project. With the cutting edge nature of Advanced Analytics, this component of the project is also deemed to be a quantitative benefit.

Reduced Highway Fatalities and Crashes

A 2019 study by the University of Central Florida (UCF) is the most comprehensive study ever conducted on the effectiveness of wrong-way driver deterrence measures². This study is provided on the project website. The UCF study focused on the extensive deployment of wrong-way countermeasures on the Central Florida Expressway, also known as the CFX.

The CFX Wrong-Way Driver Detection and Notification (WWDDN) countermeasures and their associated infrastructure are the model for the NCDOT/NCTA WWDDN sites for the FAST project. The CFX WWDDN system was estimated to have prevented slightly over one wrong-way crash system-wide per year. The authors used three different methods to estimate the benefits of the CFX system, including both significant crash reduction as well as decreased first responder calls. The three methods had lifecycle cost-benefit ratios between 4.77 to 7.20.

The interchanges in the CFX deployment are representative of the interchanges in the FAST project, with a high proportion of partial cloverleaf interchanges (the most susceptible to wrong-way activity), although the volumes are much higher.

The adaptation of these findings to the FAST application are shown in the analysis workbook.

The number of crashes avoided due to the deployment of the wrong-way driver countermeasures are estimated in Exhibit 3.

Exhibit 3 – Project Crash Reduction Factors

Project	Crash Reduction (Crashes/Year)				
	Fatal	Incapacitating Injury (A)	Non-incapacitating Injury (B)	Possible Injury (C)	Property Damage Only (PDO)
Component Five: Wrong-Way Driver Detection and Notification Systems – Toll NC-540 Corridor	0.1559	0.1111	0.1474	0.0811	0.1773

Source: HNTB safety analysis.

The total annual value for crash severity is based on 2020 Benefit-Cost Analysis Guidance for Discretionary Grant Programs recommendations 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 \$11.1 million, discounted at 7 percent.

Economic Competitiveness

The Economic Competitiveness benefit for the project can be attributed to the projected leasing of fiber to the private sector. This will expedite the delivery of broadband to NC residents who lack such access, deploy Integrated Corridor Management elements, and provide commercial leased-line cost savings.

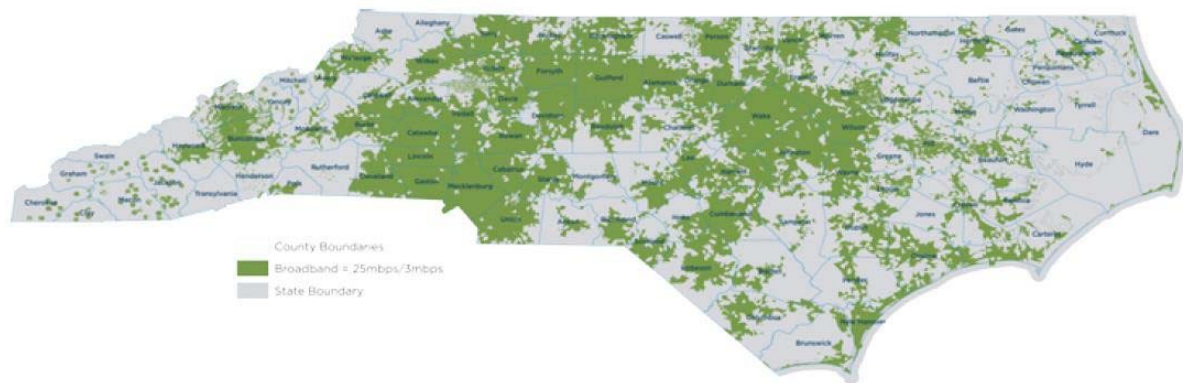
Improvements related to improving connected and automated vehicle technology are deemed to be a qualitative benefit.

Fiber Benefits

The Project utilizes transportation infrastructure investment to accomplish more than just typical transportation activities such as vehicle travel. 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, restricts educational opportunities, and limits agricultural access to applications that use big data to monitor and assess microclimate and yield data over large areas. 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 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/I-40 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,³ the value of an increase in broadband internet up to at least 4 MBPS is worth \$10.37 per household. This figure is conservative. 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.⁴

The total fiber benefit for the project amounts to \$6.9 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 to bring better cellular-based internet access to rural areas. This is a related but qualitative 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 provide benefits to 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; 4 percent was conservatively used in this analysis.⁵ 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 corridor⁶, the average trip length of 20 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.⁷ 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 \$36.2 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 Information Technology (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 \$1,000.

The North Carolina 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 Operations Center in Morrisville. The portion of this project on I-485 that will connect the Monroe Expressway to the fiber-optic backbone will allow NCTA 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 at \$2,250.

In addition, two new NCTA projects in the Charlotte area, the I-485 Express Lanes and the US-74 Express Lanes, will come online during the project period. The costs savings are estimated to be equal or greater than those for the Monroe Expressway, for each of the two projects. I-485 Express Lanes are projected to open to traffic in 2023, and US-74 Express Lanes in 2027.

The total benefit for the project amounts to \$600,000 discounted at 7 percent.

Autonomous Vehicles Benefit

The installation of fiber 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 unknowns regarding impact of the deployment on the corridor, this is deemed to be a qualitative benefit to the project.

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, 2020\$

Description	Committed NCDOT + NCTA	BUILD	Total
Component 1: Fiber-Optic Trunkline	\$3.500M	\$5.967M	\$9.467M
Component 1: Integrated Corridor Management	\$7.251M	\$0	\$7.251M
Component 2: Wrong-Way Driver Detection and Notification Systems – I-85/I-40	\$1.803M	\$0	\$1.803M
Component 3: Dynamic Curve Warning Systems	\$1.674M	\$0	\$1.674M
Component 4: Advanced Analytics	\$773K	\$0	\$773K
Component 5: Wrong-Way Driver Detection and Notification Systems – Toll NC-540	\$2.5M	\$2.245M	\$4.745M
TOTALS:	\$17.5M	\$8.213M	\$25.713M

The capital costs are applied over a two-year construction period, beginning in late 2022 and ending in mid-2024. ***The capital costs for the project discounted at 7 percent total to \$16.7 million.***

Operating and Maintenance Costs

ITS and fiber are assumed to require minimal maintenance annually, estimated at \$200,000 and \$120,000 per year, respectively.

The Wrong-Way Driver Detection and Notification Systems are assumed to require minimal maintenance annually, estimated at \$7,500 each per year based on the CFX study.

The Dynamic Curve Warning Systems sites are estimated to have a maintenance cost no more than the maintenance cost of the Wrong-Way Driver Detection and Notification System sites.

The entire system of sensors and infrastructure is expected to be replaced every 10 years, at a cost conservatively set as equal to the construction cost.

The total O&M costs over the analysis period and discounted at 7 percent is \$5.4 million.

Summary

Exhibit 6 summarizes the discounted value of the benefits discussed in this memorandum for the total Project. Taken in total with a 7 percent discount rate, the Project provides \$49.4 million dollars of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 2.95, a solid return on this investment. The net present value totals \$32.7 million.

Exhibit 6 – Total Project Benefit-Cost Analysis (2024-2043 in 2020 \$M)

NCDOT 2020 BUILD I-85/I-40/NC-540 FAST	Total Project
	20 Year Analysis Period (2024-2043)
	Values stated in 2020 \$M
	Discounted at 7%
Costs	
Capital Costs	\$16.7
Total Costs	\$16.7
Benefits	
Safety	
Reduced Highway Fatalities and Crashes	\$11.1
Sub-Total Safety Benefits	\$11.1
Economic Competitiveness	
Fiber 3rd Party Leasing Benefits	\$6.9
Reliability Savings from ICM	\$36.2
NCDOT / NCTA Fiber Savings	\$0.6
Sub-Total Economic Competitiveness	\$43.7
O&M Costs	-\$5.4
Net O&M	-\$5.4
Total Benefits	\$49.4
BC Ratio	2.95
Net Present value	\$32.7

End Notes:

¹ See BUILD 2020 Notice of Funding Opportunity, <https://connect.ncdot.gov/resources/BUILD2020-I85/Documents/BUILD%202020%20NOFO.pdf>

² Sandt, Adrian, Al-Deek, Haitham, et al “Benefit–Cost Analyses of Rectangular Flashing Beacon Wrong-Way Driving Countermeasures on Toll Road Exit Ramps in Florida”, https://connect.ncdot.gov/resources/BUILD2020-I85/Documents/Sandt%20and%20Al-Deek_TRR_Benefit%20Cost%20Analysis%20of%20RFBs_12_16_2019.pdf

³ 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>

⁴ NC Management and Budget, https://files.nc.gov/ncosbm/demog/countygrowth_cert_2016.html

⁵ 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

⁶ NCDOT Transportation Planning Branch, 2016 Freeway AADT Volumes, <https://connect.ncdot.gov/resources/State-Mapping/Documents/NCDOT2016InterstateFreewayReport.pdf>

⁷ NCDOT Traffic Survey Annual Average Daily Traffic excel report – see Supplemental Materials