NORTH CAROLINA
STATEWIDE MULTIMODAL FREIGHT PLAN
Planning for the Future of Freight Movement

HIGHWAY MODAL PROFILE - FINAL

North Carolina Statewide Multimodal Freight Plan

Highway Modal Profile

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ACRONYMS

AADTT	Average Annual Daily Truck Traffic
ACV	Autonomous and Connected Vehicle
BTI	Buffer Time Index
CRFC	Critical Rural Freight Corridor
CUFC	Critical Urban Freight Corridor
DOT	Department of Transportation
FAF	Freight Analysis Framework
FAST Act	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GA	Georgia
HPMS	Highway Performance Monitoring System
MAP-21	Moving Ahead for Progress in the 21st Century
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
MVM	Million Vehicle Miles
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NCSHP	North Carolina State Highway Patrol
NHFN	National Highway Freight Network
NHS	National Highway System
NPMRDS	National Performance Measure Research Data System
PCR	Pavement Condition Rating
PHFN	Primary Highway Freight Network
RPO	Rural Planning Organization
SHP	North Carolina State Highway Patrol
STC	North Carolina Strategic Transportation Corridors
STIP	State Transportation Improvement Program
TN	Tennessee
VA	Virginia
V/C	Volume to Capacity Ratio
USDOT	United States Department of Transportation

1.0 OVERVIEW

1.1 Purpose

Highway transport is one of the primary modes of goods movement. It accounts for the largest share of overall tonnage, representing nearly 87% of total inbound, outbound, internal and through flows for all modes combined in the state of North Carolina. Furthermore, the highway system is a critical element of the multimodal freight system as the majority of goods transported in the state utilize the highway system for at least one leg of their trip.

1.2 Methods and Data Overview

This highway modal profile draws on numerous data sources and past planning efforts to develop a comprehensive picture of the system. Data sources include the National Performance Management Research Data Set (NPMRDS), the Freight Analysis Framework (FAF), the Federal Highway Administration (FHWA) Office of Planning, Environment, and Realty, and various databases maintained by the North Carolina Department of Transportation (NCDOT). Past planning efforts that contribute to the current study include the *2017 NCDOT Statewide Multimodal Freight Plan*, the *NC Moves 2050 Plan*, the *2015 North Carolina Transportation Network and Strategic Corridors Framework*, and the 2016 report *North Carolina's Supply Chain: Conduit for Commerce and Economic Development*.

Due to the impacts of the COVID pandemic, traffic data from 2020-2022 was not used to analyze trends due to irregular patterns when compared to historic data. Future year analysis, which is projected using the FAF and NC Statewide Travel Demand Model, excludes COVID-19 related data due to irregularities observed in the freight planning process.

1.3 Section Organization

The remainder of this report is organized as follows: Section 2.0 presents an inventory of the highway system in North Carolina; Section 3.0 identifies significant freight corridors using truck volume and business location data; Section 4.0 characterizes the highway system's freight usage and performance; Section 5.0 delves deeper into statewide freight corridors by examining demand and performance on the state's highest volume freight highway corridors; Section 6.0 analyzes future performance of the highway system; and Section 7.0 presents some global highway freight challenges and opportunities.

2.0 SYSTEM INVENTORY

Based on 2021 data, NCDOT maintains approximately 80,286 miles of roadway. Of that total, secondary roads account for the largest share of the state-maintained system at about 65,113 miles, approximately 81 percent.

State roads (North Carolina Highway Routes) are a distant second to secondary roads, as they comprise about 8,139 miles (about 10%) of the state-maintained system. U.S. routes and Interstate highways comprise the remainder of the state-maintained system, accounting for 5,638 (7%) and 1,396 (2% miles, respectively, of these roadways throughout the state.

In categorizing roadways by functional classification, NCDOT uses a system consistent with what is reported as part of the Highway Performance Monitoring System (HPMS): Interstate, Principal Arterial – Other Freeways and Expressways, Principal Arterial – Other, Minor Arterial, Major Collector, Minor Collector, and Local. Based on this classification scheme, local roads comprise the majority of the state-maintained system – about 51,651 miles or 64%. Major and Minor Collectors are the next most prevalent types of roadways at 11,017 (14%) and 6,035 (8%) miles, respectively. Table 2.1 presents total mileage by roadway type and Table 2.2 presents total mileage by roadway functional classification. Figure 2.1 shows a map of the North Carolina roadway network by functional classification.

TABLE 2.1 SUMMARY OF ROADWAY TYPES

Roadway Type	Miles	Percent of Total
Interstate	1,396	1.74%
U.S. Highway	5,638	7.02%
North Carolina Route	8,139	10.14%
Secondary Route	65,113	81.10%
Total	**80,286**	**100%**

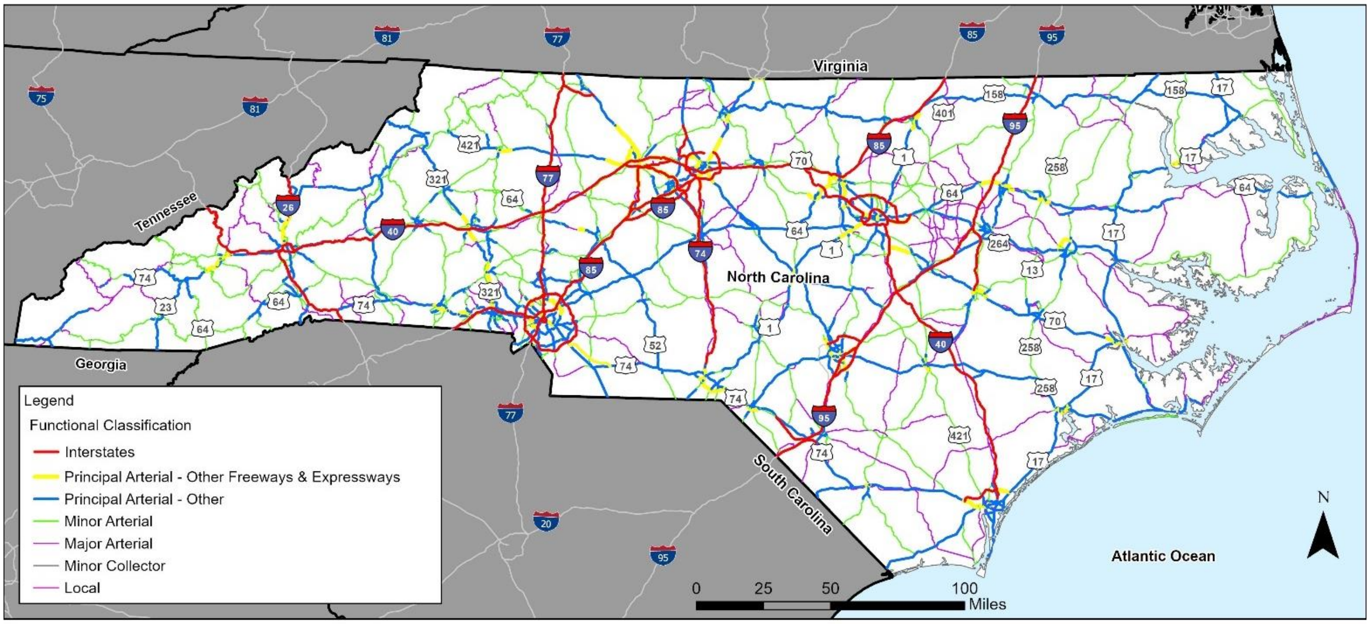
Source: North Carolina Department of Transportation Functional Class GIS Shapefile; Consultant analysis.

TABLE 2.2 SUMMARY OF ROADWAY TYPES BY FUNCTIONAL CLASSIFICATION

Roadway Type	Miles	Percent of Total
Interstate	1,396	1.74%
Principal Arterial – Other Freeways and Expressways	940	1.17%
Principal Arterial - Other	2,760	3.44%
Minor Arterial	6,035	7.52%
Major Collector	11,017	13.72%
Minor Collector	6,512	8.11%
Local	51,626	64.30%
Total	**80,286**	**100%**

Source: North Carolina Department of Transportation Functional Class GIS Shapefile; Consultant analysis.

FIGURE 2.1 FUNCTIONAL CLASSIFICATION OF NORTH CAROLINA ROADWAYS



Source: North Carolina Department of Transportation; Consultant analysis.

2.1 Freight Intermodal Connectors

National Highway System (NHS) intermodal connectors are roadways that provide first and last-mile access to the NHS primary routes. Designation as an intermodal connector depends on a roadway meeting one of several primary and/or secondary criteria established by FHWA, which are summarized in Table 2.3, for facilities that serve freight movements. Criteria primarily revolves around terminals meeting volume thresholds for trucks, 20-foot equivalent units (TEUs), or tonnages.

TABLE 2.3 CRITERIA FOR NHS INTERMODAL CONNECTOR DESIGNATION FOR FREIGHT TERMINALS

Primary Criteria	
Airports	100 trucks per day in each direction on the principal connecting route; or 100,000 tons per year arriving or departing by highway mode.
Ports	Terminals that handle more than 50,000 TEU per year, or other units measured that would convert to more than 100 trucks per day in each direction; or Bulk commodity terminals that handle more than 500,000 tons per year by highway or 100 trucks per day in each direction on the principal connecting route.
Rail	50,000 TEUs per year, or 100 trucks per day, in each direction on the principal connecting route, or other units measured that would convert to more than 100 trucks per day in each direction.
Pipelines	100 trucks per day in each direction on the principal connecting route.
Secondary Criteria	
Intermodal terminals that handle more than 20% of freight volumes by mode within a state.	
Intermodal terminals identified either in the Intermodal Management System or the state and metropolitan transportation plans as a major facility.	
Significant investment in, or expansion of, an intermodal terminal.	
Connecting routes targeted by the state, metropolitan planning organization (MPO), or others for investment to address an existing, or anticipated deficiency as a result of increased traffic.	

Source: Federal Highway Administration.

Freight-related connectors include those serving airports, truck/rail terminals, truck/pipeline terminals, and ports. According to data from the FHWA Office of Planning, Environment, and Realty, there are 20 intermodal facilities throughout the state that are included on the intermodal connector system. Those terminals and the routes that serve them are listed in Table 2.4.

TABLE 2.4 NHS FREIGHT INTERMODAL TERMINALS IN NORTH CAROLINA

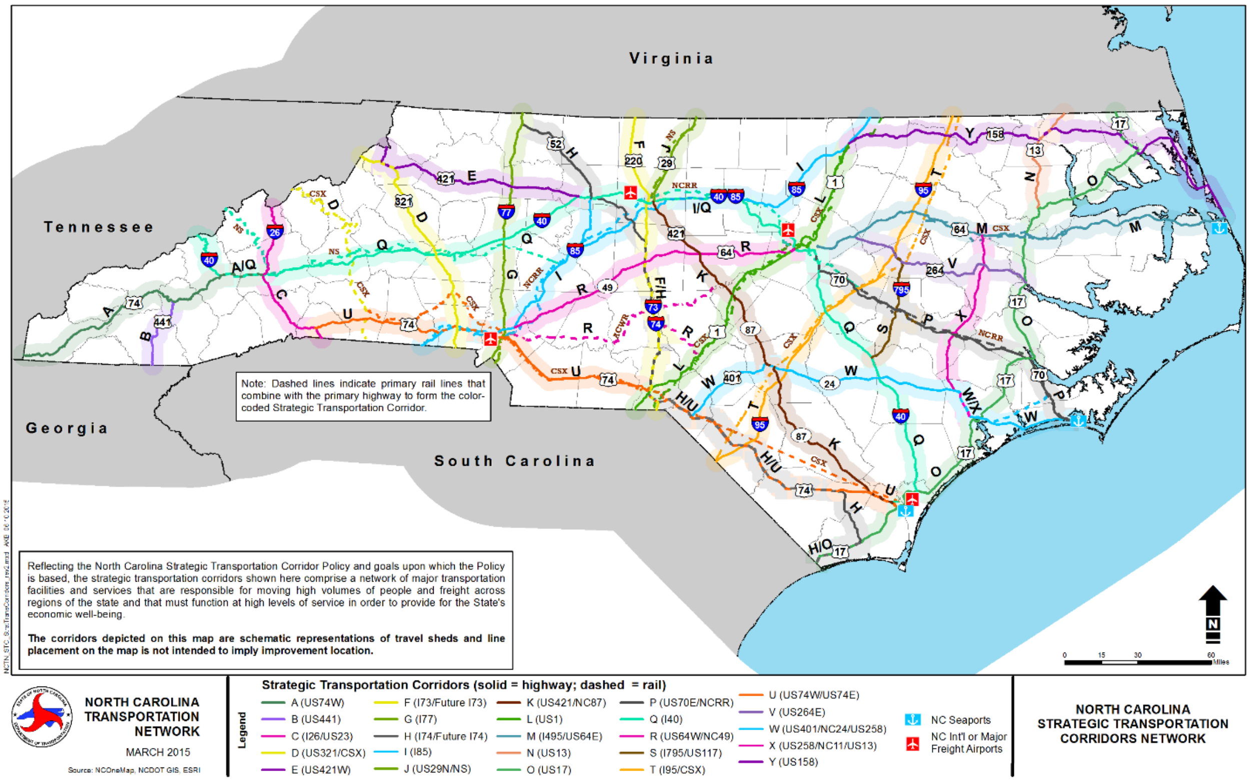
Name	Facility Type	Connector Roadways	Route Length (Miles)
Albert J. Ellis Airport - Jacksonville	Airport	N.C. 111 (Catherine Lake Road), Albert Ellis Airport Road	6.8
Asheville Regional Airport	Airport	N.C. 280 (Airport Road)	0.5
Charlotte/Douglas International Airport	Airport	SR 1490	1.5
Charlotte/Douglas International Airport	Airport	N.C. 160 (West Boulevard), Yorkmont Road	2.0
Fayetteville Regional Airport	Airport	Claudia Lee Road and Airport Road	2.8
Kinston Reg. Jetport/Global Transpark	Airport	C. F. Harvey Parkway and N.C. 58	7.9
New Hanover International Airport	Airport	23rd Street and New Hanover International Airport Entrance Road	1.3
Piedmont Triad International Airport - Greensboro	Airport	I-73 and Joseph Bryan Boulevard	1.8
Raleigh-Durham International Airport	Airport	Globe Road, Airport Boulevard, Aviation Parkway	1.2
NC State Ports - Wilmington	Port Terminal	Burnett Street, US 117 (Shipyard Boulevard), and NC 132 (College Road)	0
NC State Ports - Morehead City	Port Terminal	Served by an existing NHS route	0
Dixie Pipeline Co. - Apex	Truck/Pipeline Terminal	N.C. 55 (Williams Street)	0.8
Petroleum Pipeline Terminal - Charlotte	Truck/Pipeline Terminal	N.C. 27 between I-85 and Mount Holly Road	3.6
Petroleum Pipeline Terminal - Greensboro	Truck/Pipeline Terminal	Gallimore Dairy Road and West Market Street	1.4
Petroleum Pipeline Terminal - Selma	Truck/Pipeline Terminal	Buffaloe Road	1.0
Star Enterprise Pipeline Terminal	Truck/Pipeline Terminal	Shaw Mill Road and Murchinson Road	1.1
CSX Freight Intermodal Facility - Charlotte	Truck/Rail Facility	Hovis Road and N.C. 16	1.9
CSX Freight Intermodal Terminal – Rocky Mount	Truck/Rail Facility	College Road	0.3
Norfolk Southern - Winston-Salem	Truck/Rail Facility	Williston Road and Old Walkertown Road	6.7
Norfolk Southern - Charlotte	Truck/Rail Facility	N. Brevard Street and Caldwell Street/Parkwood Avenue	1.0
Norfolk Southern - Greensboro	Truck/Rail Facility	High Point Road, Meadowview Road, Patterson Street, and Merritt Drive	1.9

Source: Federal Highway Administration Office of Planning, Environment, and Realty.

2.2 Strategic Transportation Corridors

The North Carolina Strategic Transportation Corridors (STC) network consists of key multimodal transportation corridors that connect statewide and regional transportation-dependent activity centers. Freight activity was a primary element of the development of the STC network as high-truck volume and freight rail corridors were identified as part of the analysis. In addition to the state's interstate highways, these included U.S. 52, U.S. 74, U.S. 70, U.S. 64/N.C. 49, and U.S. 421/N.C. 87, among others. As a result of the analysis, 25 distinct corridors were selected to comprise the STC. These are listed in Table 2.5 and depicted in Figure 2.2.

FIGURE 2.2 NORTH CAROLINA STRATEGIC TRANSPORTATION CORRIDORS



Source: NCDOT, North Carolina Transportation Network and Strategic Corridors Framework, August 2015.

TABLE 2.5 NORTH CAROLINA STRATEGIC HIGHWAY TRANSPORTATION CORRIDORS

Corridor Label	Corridor	Corridor Limits
A	U.S. 74 W	NC-TN State Line to I-26
B	U.S. 23/U.S. 441	NC-GA State Line to U.S. 74
C	I-26/U.S. 23 W	NC-SC State Line to NC-TN State Line
D	U.S. 321	NC-SC State Line to NC-TN State Line
E	U.S. 421	NC-TN State Line to I-40
F	I-73/Future I-73	NC-SC to NC-VA State Lines
G	I-77	NC-SC to NC-VA State Lines
H	I-74/Future I-74	NC-SC State Line to I-77
I	I-85/I-285 Spur	NC-SC to NC-VA State Lines with Future I-285 Spur to Winston-Salem
J	U.S. 29	I-40 to VA State Line
K	U.S. 421/NC 87	U.S. 117 in New Hanover County to I-40 in Guilford County
L	U.S. 1	NC-SC State Line to I-85
M	Future I-495/U.S. 64 E	I-440 in Wake County to N.C. 12 in Dare County
N	U.S. 13	U.S. 17 in Bertie County to NC-VA State Line
O	U.S. 17	NC-SC to NC-VA State Lines
P	U.S. 70 E	I-440 in Wake County to Morehead City Port
Q	I-40	NC-TN State Line through Research Triangle Park to U.S. 117 in Wilmington
R	U.S. 64 W/NC 49	I-85 in Mecklenburg County to I-40 in Wake County
S	I-795/U.S. 117	I-95 to I-40
T	I-95	NC-SC to NC-VA State Lines
U	U.S. 74 W/U.S. 74 E	I-26 in Polk County through Mecklenburg County to U.S. 117 in Wilmington
V	U.S. 264 E	U.S. 63 E in Wake County to U.S. 17 in Beaufort County
W	U.S. 401/N.C. 24/U.S. 258	I-74 in Scotland County to Morehead City Port
X	U.S. 258/N.C. 11/U.S. 13	U.S. 17 in Onslow County to Pitt County to U.S. 64 E in Edgecombe County
Y	U.S. 158	I-85 in Vance County to U.S. 64 in Dare County

Source: NCDOT, North Carolina Transportation Network and Strategic Corridors Framework, August 2015.

STC corridors that facilitate rail and intermodal freight transport include:

- **Corridor D** provides connectivity to the CSX rail line that operates from the northern North Carolina mountains to the coal fields in the Appalachians. This rail line is a primary coal route for delivery of Appalachian coal to North Carolina electric generation plants.

- **Corridor I** serves the state's Piedmont Crescent, carrying high volumes of freight along the NCRR between the Charlotte and Durham major metropolitan areas.

- **Corridor J** provides STRACNET connectivity through the NS Crescent Corridor. The NS mainline located along this corridor connects Greensboro to Danville, Virginia.

- **Corridor L** is a regional connector that runs along the US 1 corridor from the South Carolina state line to I-85 near Henderson, providing mostly regional and interregional passenger rail service along the CSX rail line. Much of the freight rail has been shifted to the CSX A-Line that parallels the I-95 corridor.
- **Corridor M** parallels a secondary CSX railroad carrying relatively lower volumes of freight but provides needed access to manufacturing and natural resource markets in eastern North Carolina.
- **Corridor P** includes the NCRR mainline, which connects the Port of Morehead City to Raleigh, where it connects to the CSX in Johnston County.
- **Corridor Q** connects to the NCRR and the secondary NS line from Salisbury through Asheville to Tennessee. This corridor is the state's most important cross-state corridor, linking all three regions and more activity centers than any other.
- **Corridor R** includes the ACWR, a secondary freight railroad connecting Mecklenburg County to Sanford and Lee County.
- **Corridor T** includes the CSX rail line that runs parallel to the I-95 corridor, providing major rail access in North Carolina, connecting major regional employment centers in the Coastal Plains region between the South Carolina and Virginia state lines.
- **Corridor U –** is served by the CSX rail line between Charlotte and Wilmington, providing freight rail access to the port at Wilmington.

3.0 FREIGHT SIGNIFICANT CORRIDORS

In this analysis, portions of the state's highway system with high truck volumes and clusters of freight-intensive industries are identified using business location data from Data Axle and census tracts from the U.S. Census Bureau. By comparing the locations of freight activity as indicated by these two data sources, the analysis can determine the most significant freight corridors statewide. This is important because it begins to form the foundation by which a statewide highway freight system can be developed.

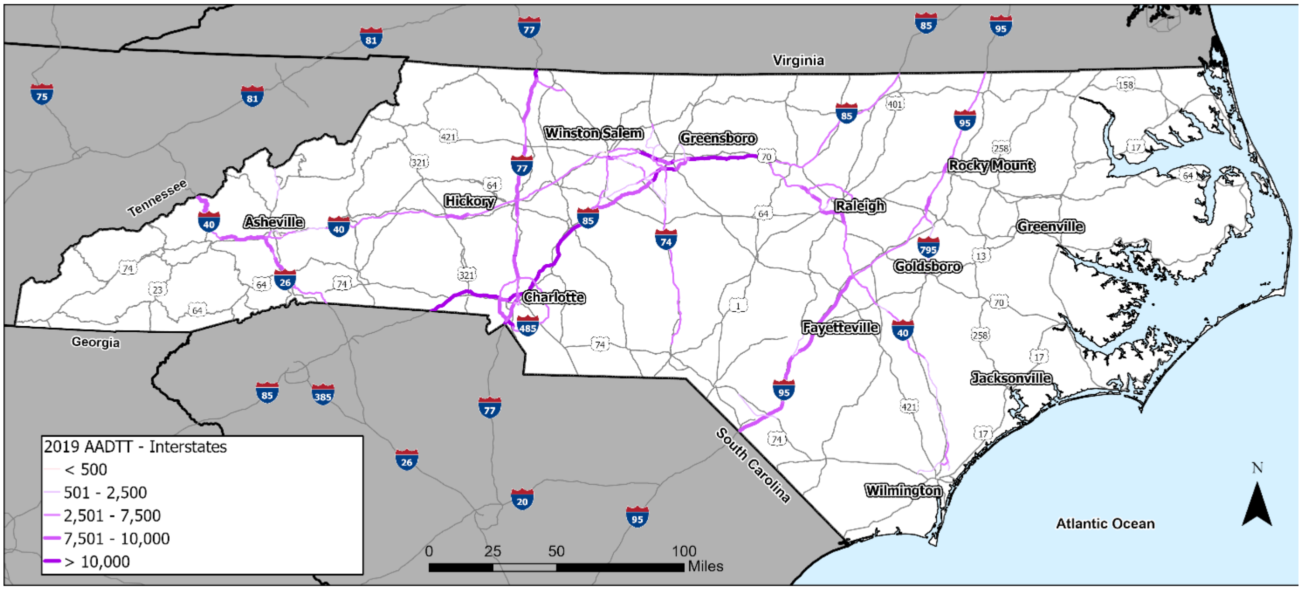
3.1 Truck Volumes

Truck count data is an important element to identifying significant freight corridors. The NCDOT Traffic Survey Group develops truck volume data. Due to the impact of COVID-19 on travel patterns seen throughout the nation, the 2019 truck volumes were used since that was the most recent year of travel matching historical trends. In Figure 3.1, roadways with higher truck volumes are indicated by thicker, heavier lines while those with less truck activity are indicated by thinner, lighter lines.

Figure 3.1 indicates that most of North Carolina's truck flows occur on the interstate highway system. In particular, the highest Average Annual Daily Truck Traffic (AADTT) in the state are estimated to occur on I--85 between Greensboro and Durham. Nearly 16,000 trucks per day are estimated to utilize this corridor. In general, I-85 is the heaviest utilized freight corridor in North Carolina based on truck volumes. Truck volumes on I-85 range from 10,000 to 16,000 trucks per day.

Other interstate highways with particularly high truck AADTTs include I-77, I-40, I-26 and I-95. I-77 between I-40 and I-485 (north of Charlotte) carries between 8,000 and 10,000 trucks per day. I-26 south of Asheville carries nearly 9,000 trucks daily. I-40 between Winston-Salem and Greensboro carries between 8,000 to 11,000 trucks daily. I--95 near its interchange with I-40 carriers over 9,000 trucks per day.

FIGURE 3.1 TRUCK VOLUMES ON INTERSTATE HIGHWAYS



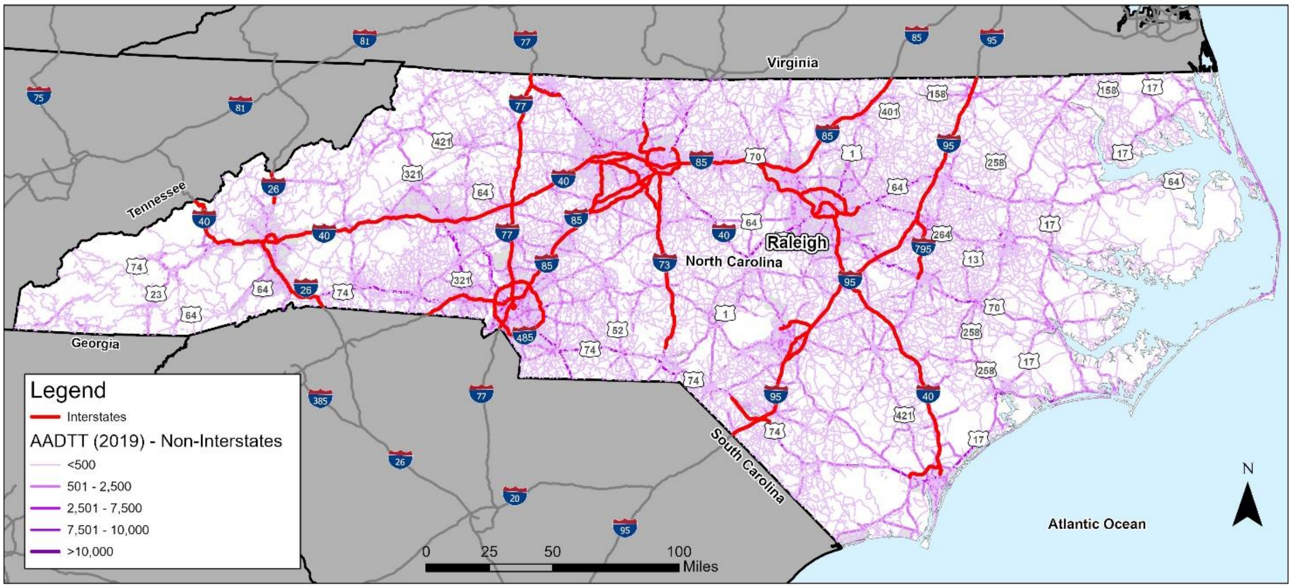
There are several non-interstate highways that are important freight corridors as indicated by daily truck volumes.

Figure 3. presents truck flows on non-interstate highways in North Carolina. Some of these highways achieve daily truck volumes that are comparable to those experienced by the interstate highway system. Among the highest used non-interstate highway freight corridors are U.S. 74 and U.S. 70, which provide east-west connectivity over the southern portion of North Carolina and between Morehead City and Raleigh. At its busiest, portions of U.S. 74 transports nearly 5,000 trucks per day. U.S. 70 carries nearly 3,000 trucks daily at its busiest portions.

Direct connectivity between Fayetteville, Fort Bragg, and the Piedmont Triad Region is provided by the route consisting of U.S. 421, N.C. 87 and N.C. 24/N.C. 87. This route has significant freight volumes with portions experiencing over 3,000 trucks per day. U.S. 29 and U.S. 220 provide important connections between the Piedmont Triad and the Danville and Martinsville Regions of Virginia, respectively. Over 3,000 trucks per day utilize the U.S. 220 corridor between Greensboro, NC and Martinsville, VA. Over 5,000 trucks per day utilize the U.S. 29 corridor between Greensboro, NC, and Danville, VA.

U.S. 321 between Gastonia and Hickory is also a major non-interstate highway freight corridor. It transports over 5,000 trucks daily. In addition to providing access to the Charlotte Region, U.S. 321 also provides alternate access to I-85 and I-77 south for shippers and motor carriers in Hickory.

FIGURE 3.2 TRUCK VOLUMES ON NON-INTERSTATE HIGHWAYS



Source: North Carolina Department of Transportation; Consultant analysis.

3.2 Freight Clusters

The locations of freight-intensive industries in the state point to areas of high truck traffic and freight activity. For purposes of this analysis, freight-intensive industries are defined as those with primary North American Industry Classification System (NAICS) codes corresponding to manufacturing, construction, wholesale trade, transportation and warehousing, agriculture, and mining. Figure 3.3 shows the major urban regions in North Carolina. Figure 3.4 presents a map of the locations of freight-intensive industries in North Carolina. Largely, these facilities are clustered in the state's major metropolitan regions: Charlotte, the Triangle (Raleigh/Durham/Chapel Hill), the Triad (Greensboro/Winston-Salem/High Point), Fayetteville, Wilmington, and Asheville regions.

FIGURE 3.3 MAJOR NORTH CAROLINA URBAN REGIONS

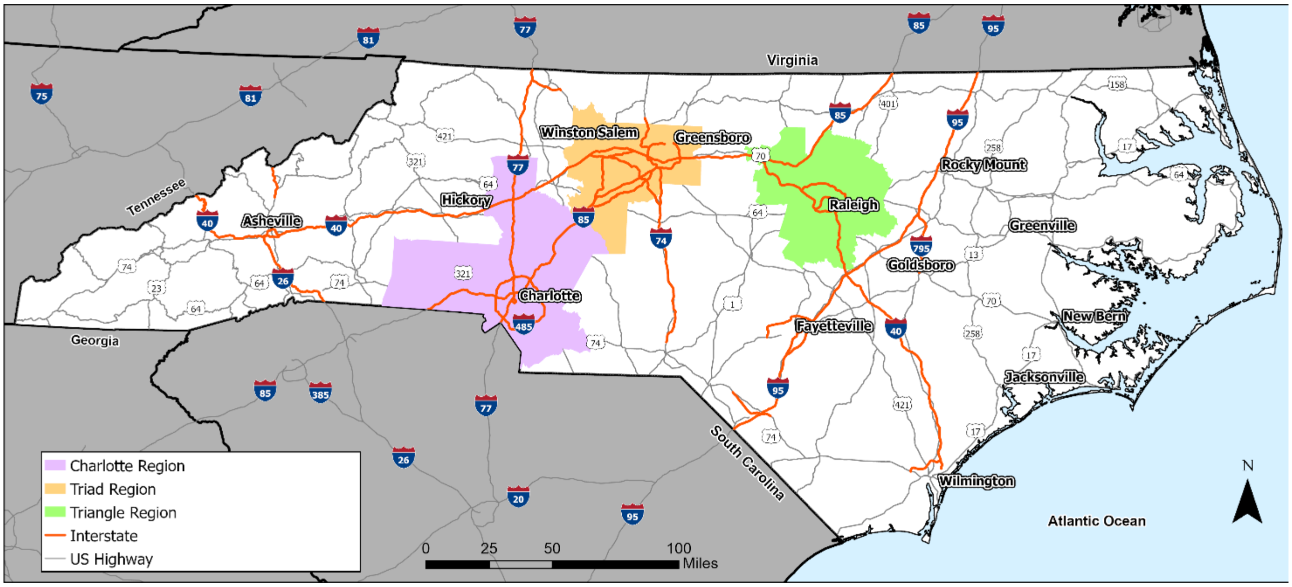
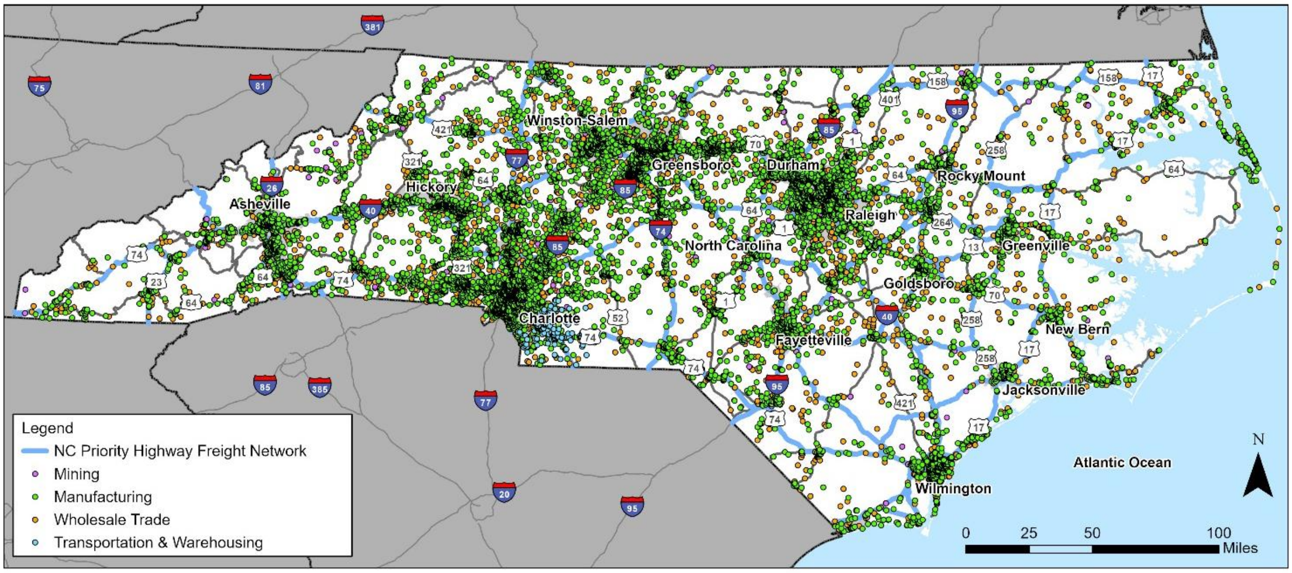


FIGURE 3.4 FREIGHT-INTENSIVE INDUSTRIES IN NORTH CAROLINA BY ECONOMIC SECTOR

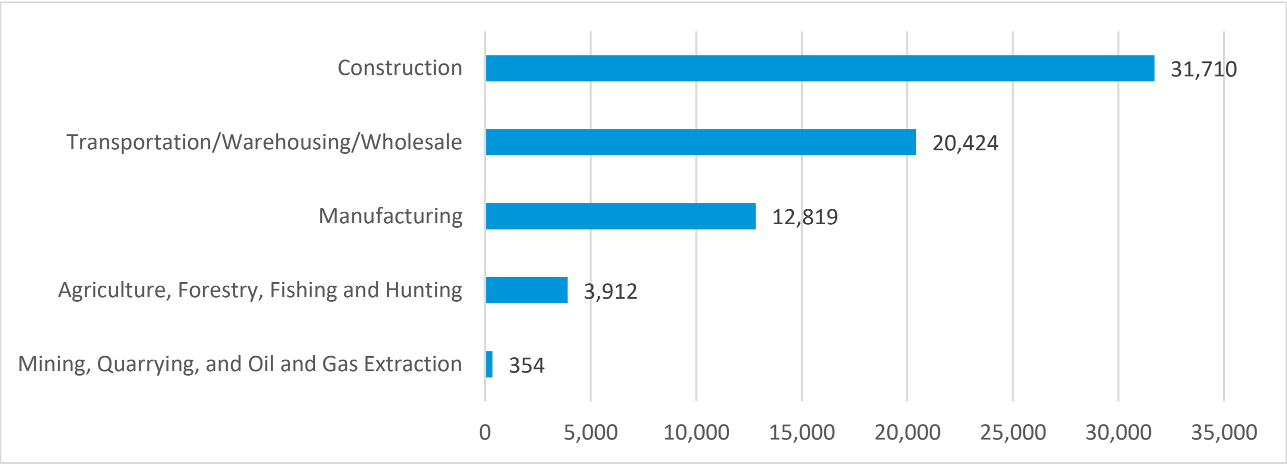


Source: Data Axle

There are nearly 69,000 freight-intensive business locations throughout the state as shown in Figure 3.5. The construction industry, with nearly 32,000 establishments (approximately 45%), represents the largest industry. Transportation/warehousing/wholesale was the second-most common type of freight facility, with over 20,000 throughout the state (about 30%). Facilities in this category include warehouses, distribution centers and wholesale trade centers, among others. Facilities designated for manufacturing and agriculture/forestry/fishing/hunting uses are prevalent throughout the state, comprising nearly 19% and 6%, respectively. There are very few mining facilities throughout the state, 354 or 0.5%, although this type of land use can also generate significant numbers of truck trips.

The magnitude of truck volumes along I-85 helps confirm the importance of this corridor to statewide freight movements. I-85 is the major truck freight route between the Atlanta, GA, region and the northeastern United States. I-85 is a potential area of economic interest to the state due to the high truck volume and freight-intensive facilities alongside the highway. While other highways in the state may have greater through movements, they do not economically contribute to the state .

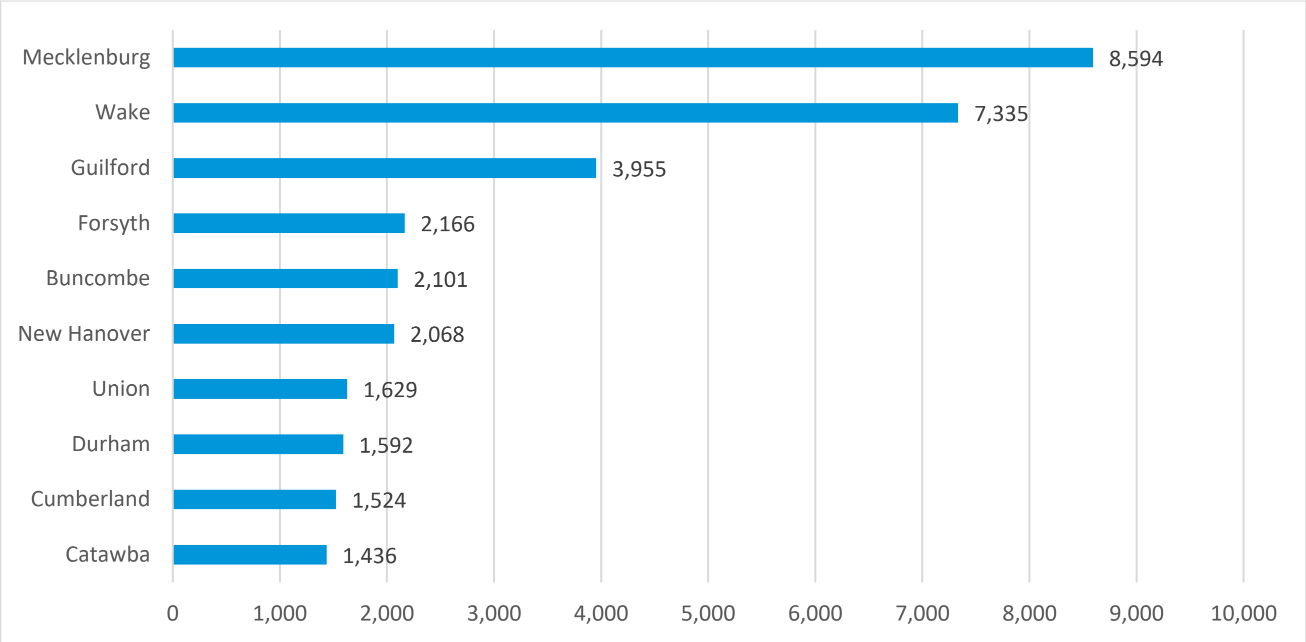
FIGURE 3.5 NUMBER OF FREIGHT-INTENSIVE BUSINESS LOCATIONS BY INDUSTRY



Source: Data Axle; Consultant analysis.

Figure 3.6 presents the top ten counties by number of freight-intensive facilities. These counties represent approximately 47% of all freight-intensive facilities throughout the state, the remaining counties comprise about 53%. The counties that comprise North Carolina's major metropolitan areas are represented in this ranking. Mecklenburg County ranks highest with 8,594 facilities, or about 12% of the total. The Triangle Region follows a similar pattern to the Charlotte Region. Wake County has 7,335 freight-intensive facilities, while Durham County has 1,592 facilities. Together, these core counties of the Triangle Region represent approximately 13% of freight-intensive businesses throughout the state. The Triad Region, Forsyth, and Guilford Counties combined have over 6,000 freight-intensive facilities or about 9% of all facilities.

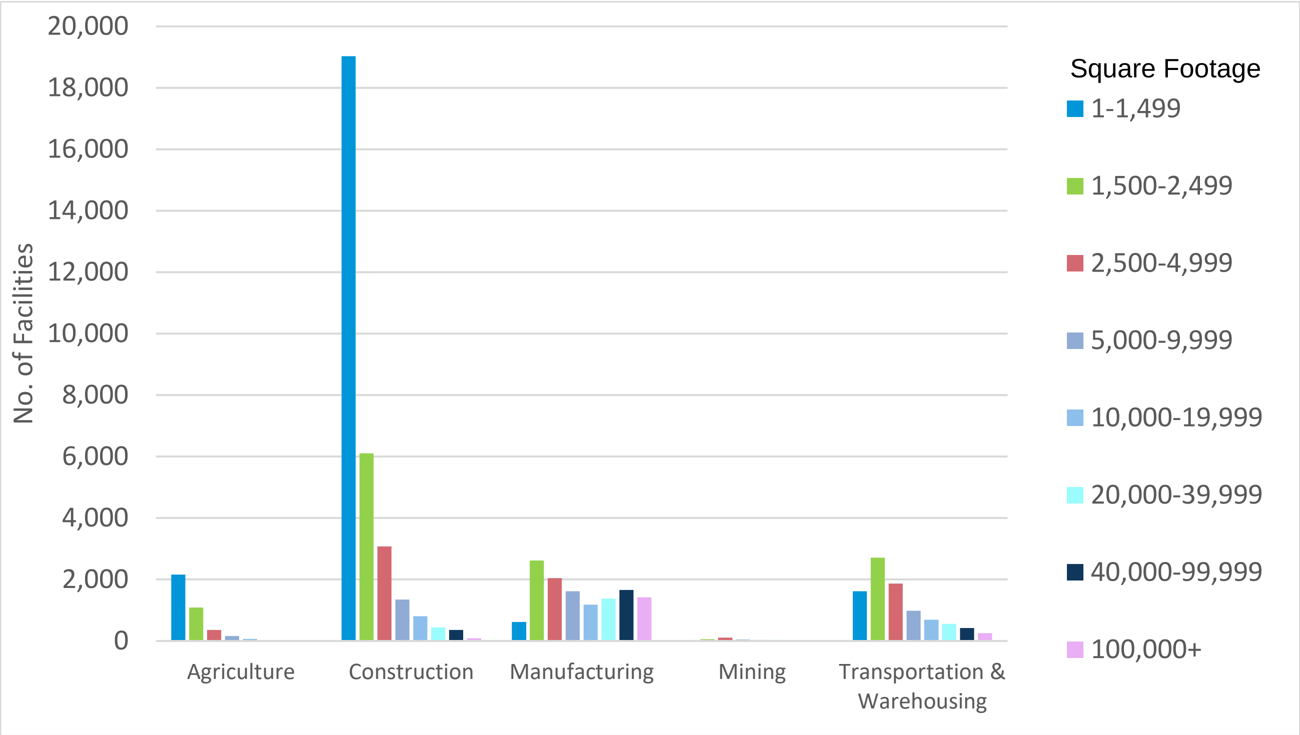
FIGURE 3.6 TOP TEN COUNTIES BY NUMBER OF FREIGHT-INTENSIVE BUSINESS FACILITIES



Source: Data Axle; Consultant analysis.

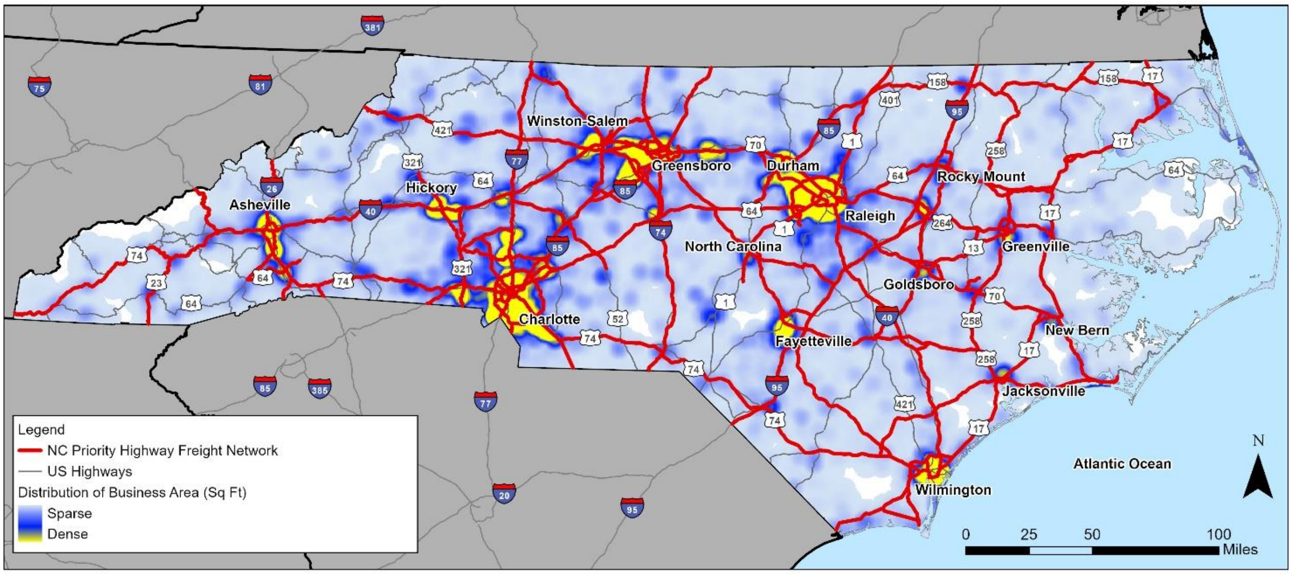
To identify those areas of the state with the highest intensity of freight land uses, the locations of freight-intensive facilities are weighted by square footage according to the information contained in the Data Axle database. The database contains eight different categories for firm size by total square footage (see Figure 3.7). Firms belonging to the lowest size category (or with no information) received a weight of one, while those belonging to the largest size category received a weight of four. In this manner, the analysis will identify clusters of freight-intensive land uses by both location and total square footage. The spatial unit utilized for this analysis is the census tract. The results of the analysis are presented in Figure 3.8.

FIGURE 3.7 DISTRIBUTION OF TOTAL SQUARE FOOTAGE OF FREIGHT-INTENSIVE FACILITIES BY INDUSTRY SECTOR



Source: Data Axle; Consultant analysis.

FIGURE 3.8 FREIGHT-INTENSIVE FACILITIES WEIGHTED BY SQUARE FOOTAGE



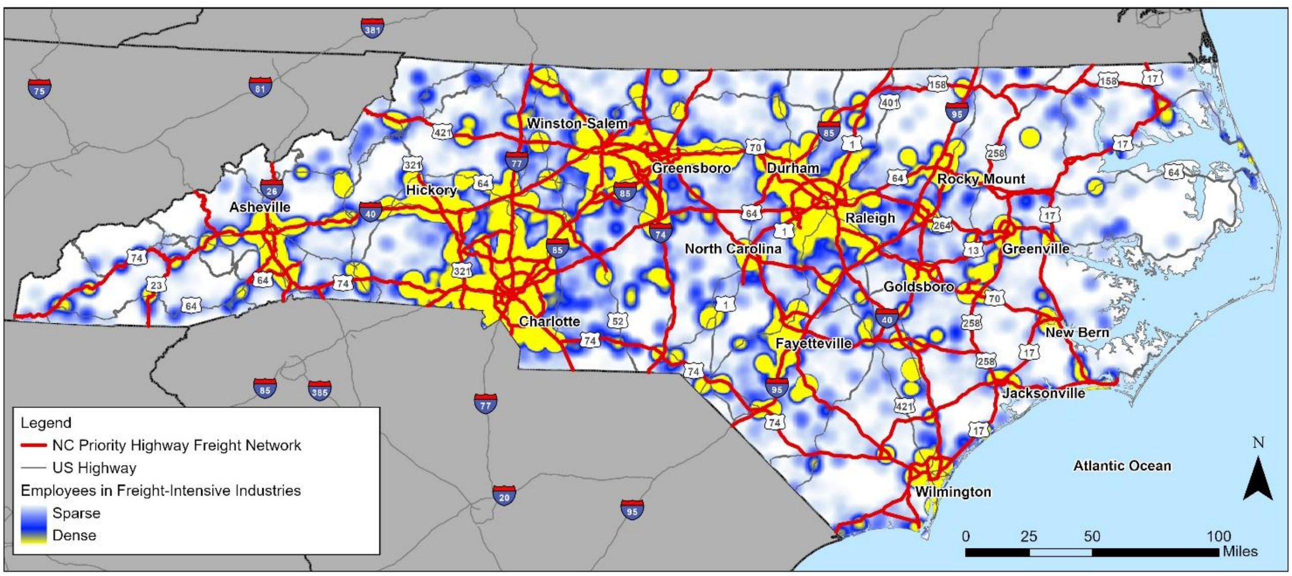
Source: Data Axle; Consultant analysis.

The results of this portion of the analysis indicate that most intense freight-related land uses are generally located along the state's major highways, just outside the cores of its major metropolitan areas. Census tracts within the state's major metropolitan areas show high levels of freight-related land uses. However, these locations appear to be outside of the urban core of these regions and located in suburban and exurban communities. This is likely a result of land typically being less expensive and more available in larger lot sizes farther away from city centers.

The I-85 corridor passes through or is proximate to several of the top ten freight-intensive industry counties. I-85 passes through Mecklenburg, Guilford, and Durham counties. Union, Forsyth, and Wake counties have relatively easy access to I-85 via other interstates and highways. A positive correlation can be made between the number of freight-intensive industries and the importance of I-85 to goods movement throughout the state and the East Coast.

Similar results are observed when the spatial distribution of employees in freight-intensive industries is analyzed. These results are shown in Figure 3.9. The results indicate that the largest distribution of workers in freight-intensive industries are located along North Carolina's major highways and near the cores of its major metropolitan areas. Both analyses, employment and land use, indicate that freight-related economic activity is much higher in the central portion of the state (between I-77 and I-95), as opposed to the eastern and western portions of the state.

FIGURE 3.9 EMPLOYMENT IN FREIGHT-INTENSIVE INDUSTRIES



Source: Data Axle; Consultant analysis.

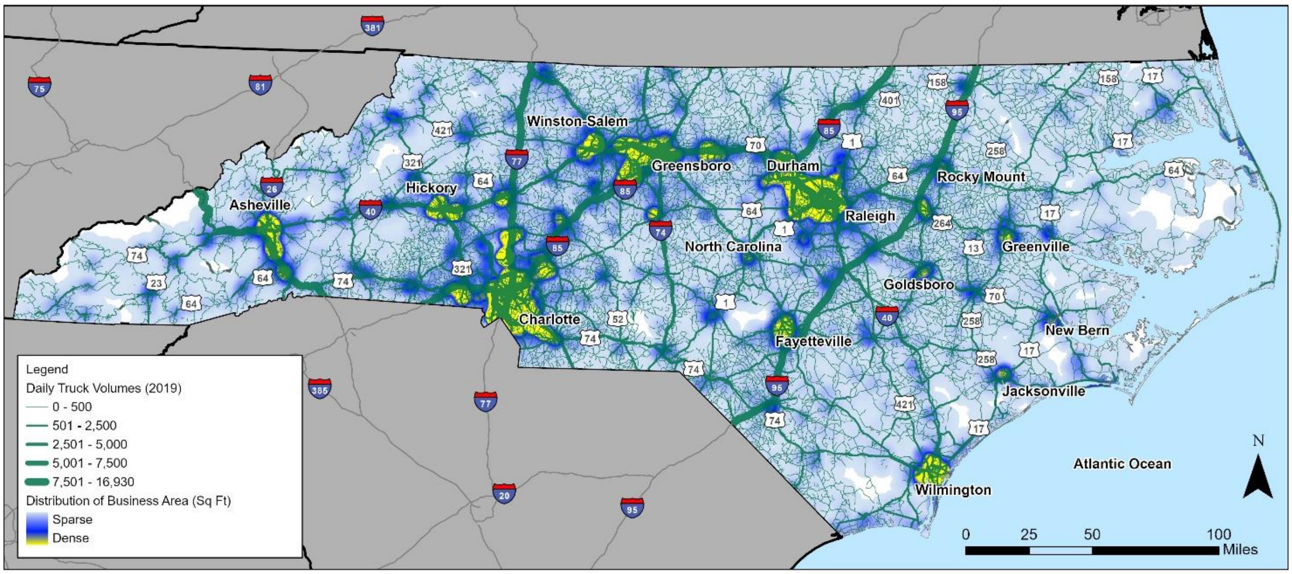
3.2.1 Comparison to Truck Volumes

Several of the highest concentrations of freight-intensive land uses in North Carolina are proximate to the most heavily utilized truck routes, as shown in Figure 3.10, which overlays freight-intensive land uses with the AADTT. Interstate highways, particularly I-26, I-40, I-77, I-85, and I-95 all have areas of freight-intensive land uses located directly along or proximate to their routes. Besides interstate highways, many U.S. and N.C. routes exhibit a confluence of heavy truck volumes and freight land uses. For instance, the U.S. 321 corridor, which provides north-south connectivity in the western part of the state, has freight-intensive land uses along nearly its entire length from Hickory to Gastonia. This corridor exhibits significant truck volumes, corresponding to land use, with activity reaching over 5,000 trucks per day in some locations. Similarly, U.S.

64, U.S. 70, U.S. 74, and U.S. 264 all connect freight-intensive land uses in the northeastern portion of the state to I-95, the Triangle area, and the Norfolk-Virginia Beach area of Virginia.

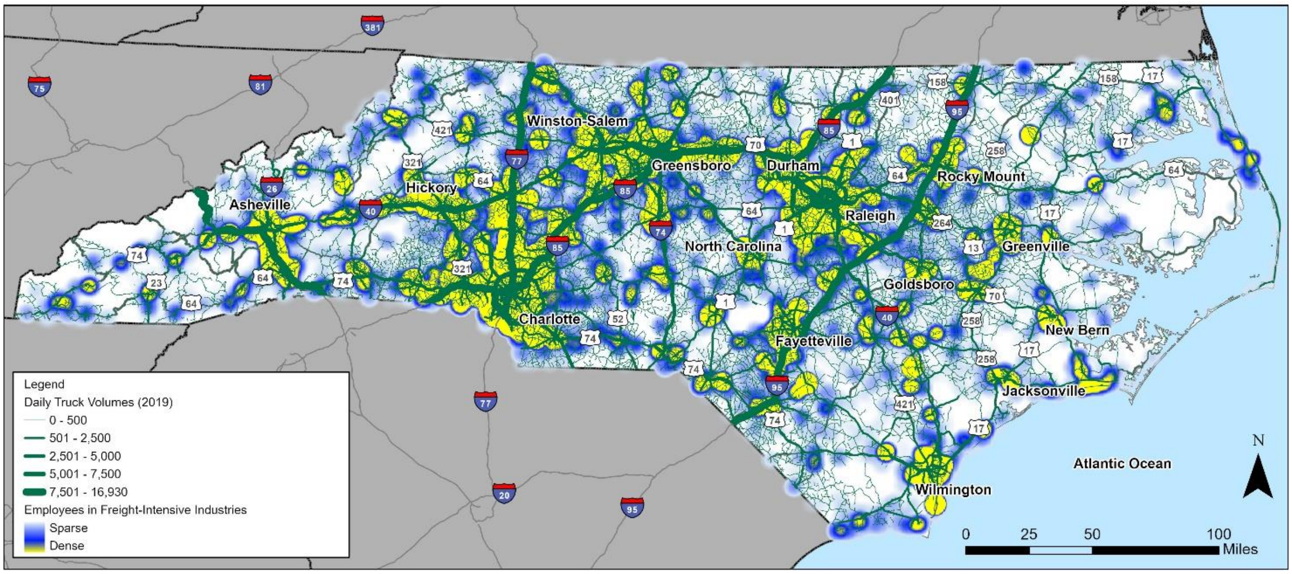
A similar dynamic is observed when truck volumes are compared to freight-related employment. Freight-related employment is concentrated in the state's major metropolitan areas and alongside interstate highway corridors (Figure 3.11). Non-interstate highway corridors such as U.S. 64, U.S. 70, U.S. 74, U.S. 264, and U.S. 321 show significant levels of truck activity as well as freight-related employment relative to other portions of the state. For shippers east of I-95 and west of I-77, non-interstate highways provide primary access to the interstate highway system, the ports at Wilmington and Morehead City, and access to the state's major metropolitan areas.

FIGURE 3.10 TRUCK VOLUMES AND FREIGHT-INTENSIVE LAND USES



Source: Data Axle; North Carolina Department of Transportation; Consultant analysis.

FIGURE 3.11 TRUCK VOLUMES AND EMPLOYMENT IN FREIGHT-INTENSIVE INDUSTRIES



Source: Data Axle; North Carolina Department of Transportation; Consultant analysis.

4.0 NETWORK USAGE AND PERFORMANCE

4.1 Commodity Flows

According to commodity flow data released as part of version 5 of the Freight Analysis Framework (FAF5) and additional analysis to estimate through flows, over 600 million tons of cargo were transported over North Carolina's highways in 2017. Trucking accounted for the largest share of overall tonnage by mode representing nearly 83% of total inbound, outbound, internal, and through flows for all modes combined. Table 4.1 shows that nearly 43% of total truck flows were internal to the state, meaning they began and ended within North Carolina. Truck flows inbound to North Carolina and outbound from the state had equal shares of total truck flows, 14%. Through truck flows, those with an origin and destination outside of North Carolina but traveling through the state, comprised 29%.

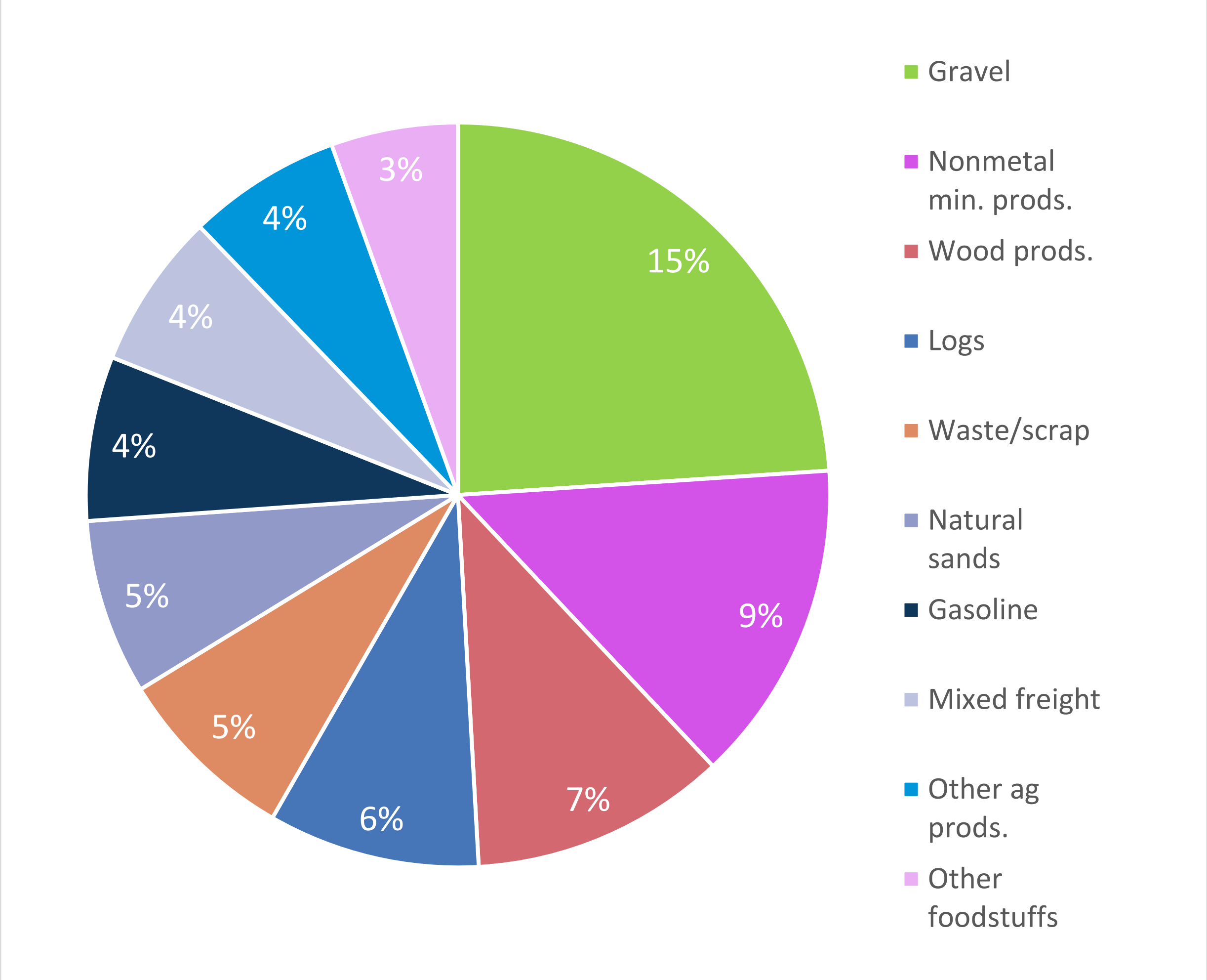
TABLE 4.1 HIGHWAY COMMODITY FLOWS BY DIRECTION, 2017

Direction	2017 Tonnage	Percent of Total
Inbound	78,553,000	14%
Outbound	74,636,000	14%
Internal	235,475,000	43%
Through	216,000,000	29%
Total	604,664,000	**100%**

Source: Disaggregate Freight Analysis Framework version 5; Consultant analysis.

The predominant commodities, based on weight, that are transported by highway primarily consist of bulk goods such as gravel, nonmetal mineral products, and wood products. "Mixed Freight" is a catch-all commodity code that consists of grocery and convenience store items, supplies and food for restaurants, hardware or plumbing supplies, and office supplies, in addition to miscellaneous items.[1] The top ten commodities moved in terms of tonnage generated in the state, shown in Figure 4.1, account for nearly 62% of the truck tonnage.

FIGURE 4.1 TOP TEN COMMODITIES BY TOTAL TONNAGE (2017)



Source: Disaggregate Freight Analysis Framework version 5; Consultant analysis

Note: Prods. = Products; Min. = Minerals; Ag = Agricultural

[1] U.S. Census Bureau. 2017 Commodity Flow Survey Standard Classification of Transported Goods (SCTG): SCTG Commodity Codes. https://www.census.gov/content/dam/Census/library/publications/2017/econ/ec17tcf-us.pdf

4.2 Truck Congestion

Truck congestion is indicated by the annual average truck speeds on the highway system. In this analysis, annual average truck speeds are derived from travel time data from the National Performance Management Research Data Set (NPMRDS). The NPMRDS provides average travel times for trucks, passenger vehicles and all vehicles combined aggregated to 5-minute intervals for roadways that are part of the NHS. Data from 2019 was utilized for this analysis. In the analysis, travel time data was analyzed in four distinct periods capturing an entire 24-hour period:

- Morning peak – 6 – 10 a.m. (Eastern Standard Time, EST)
- Midday peak – 10 a.m. – 3 p.m. (EST)
- Evening peak – 3 – 7 p.m. (EST)
- Off Peak – 7 p.m. – 6 a.m. (EST)

4.2.1. Interstate Highways

This analysis uses 55 miles per hour (mph) as the reference speed for truck congestion. Meaning average speeds above 55 mph are considered uncongested and any speed below 55 mph is considered congested for trucks on interstate highways. The results of the analysis show that the majority of the state's interstate highway system provides for uncongested truck travel. As shown in Table 4.2, approximately 89% of the interstate system (by mileage in both directions) is uncongested during the morning peak. Conditions slightly improve during the midday period as 93% of the system is uncongested. The evening peak has the worst overall performance, with 86% of the system consisting of uncongested truck travel.

TABLE 4.2 SUMMARY OF AVERAGE TRUCK CONGESTION FOR INTERSTATE HIGHWAYS

Peak Period	Total Mileage Uncongested (Both Directions)	Percent of Total Mileage that is Uncongested
Morning	2,271	89%
Midday	2,367	93%
Evening	2,198	86%
Off Peak	2,428	95%
Total Mileage (Both Directions)	**2,551**	**100%**

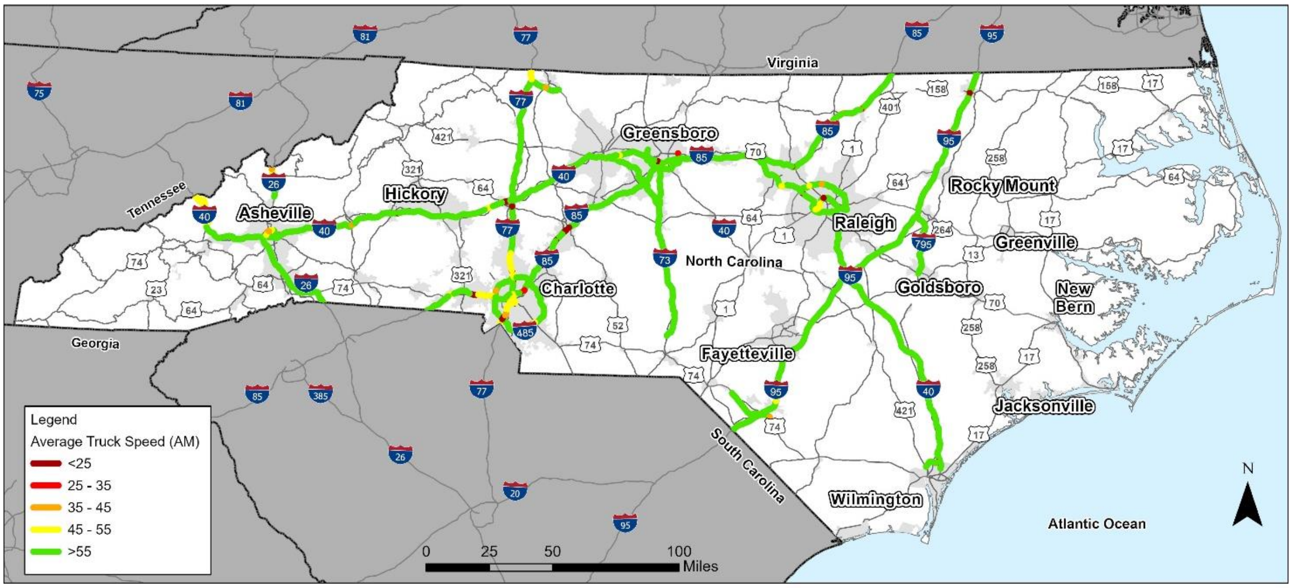
Source: 2019 National Performance Research Data Set; Consultant analysis.

Overwhelmingly, truck congestion is limited to the state's largest metropolitan areas – the Triangle the Triad, and the Charlotte metropolitan area. These areas all have significant commuter activity that occurs on the interstate highway system and competes with trucks for capacity. In the Triangle Region, truck congestion is most pronounced near the City of Raleigh along the I-40 and I-440 corridors. There is also significant congestion along I-540 near its interchange with I-40 and N.C. 540. In the Charlotte Region, truck congestion is heaviest along I-77 through the core of the region and north of the I-485 perimeter near Huntersville. The southwest portion of I-485 (between U.S. 74 and I-85) also exhibits poor performance.

Truck congestion is most pronounced in the Triad along the portion of I-40 bounded by U.S. 421 on the western side of the City of Winston-Salem.

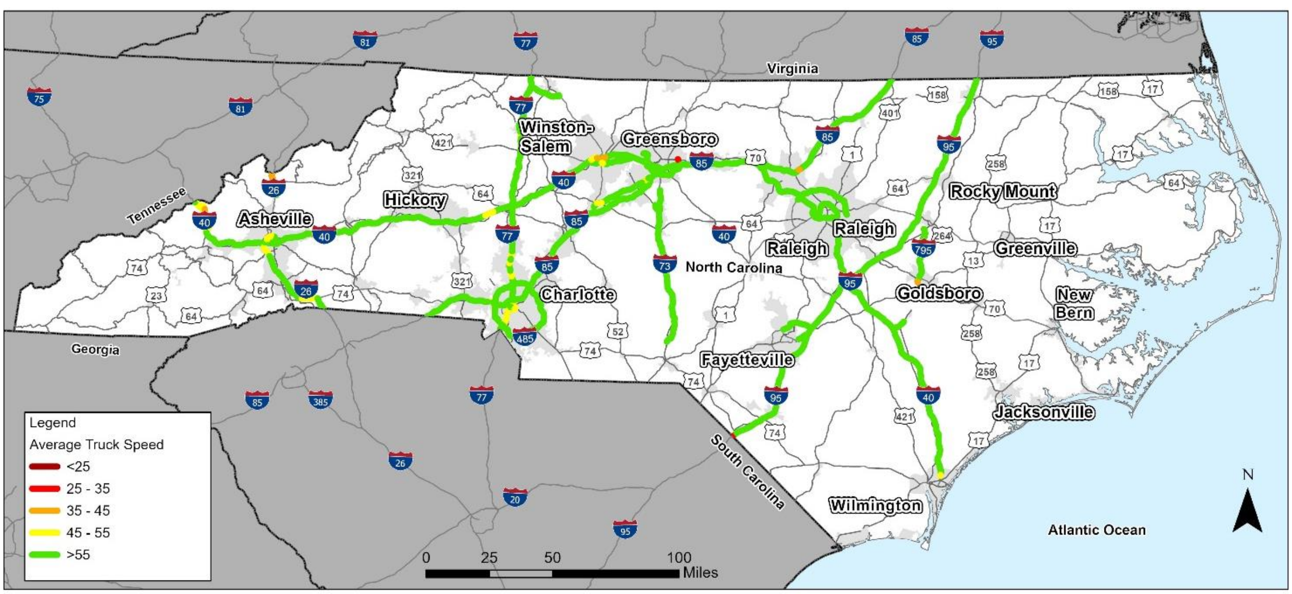
Regions of the state outside of these areas have considerably less congestion as indicated by average truck speeds on the interstate highway system. However, some truck congestion is observed in the Asheville Region. Truck congestion in the Asheville Region is largely limited to I-240. Figure 4.2 to Figure 4.5 shows the average truck speeds on interstate highways for different time periods throughout the day.

FIGURE 4.2 MORNING PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



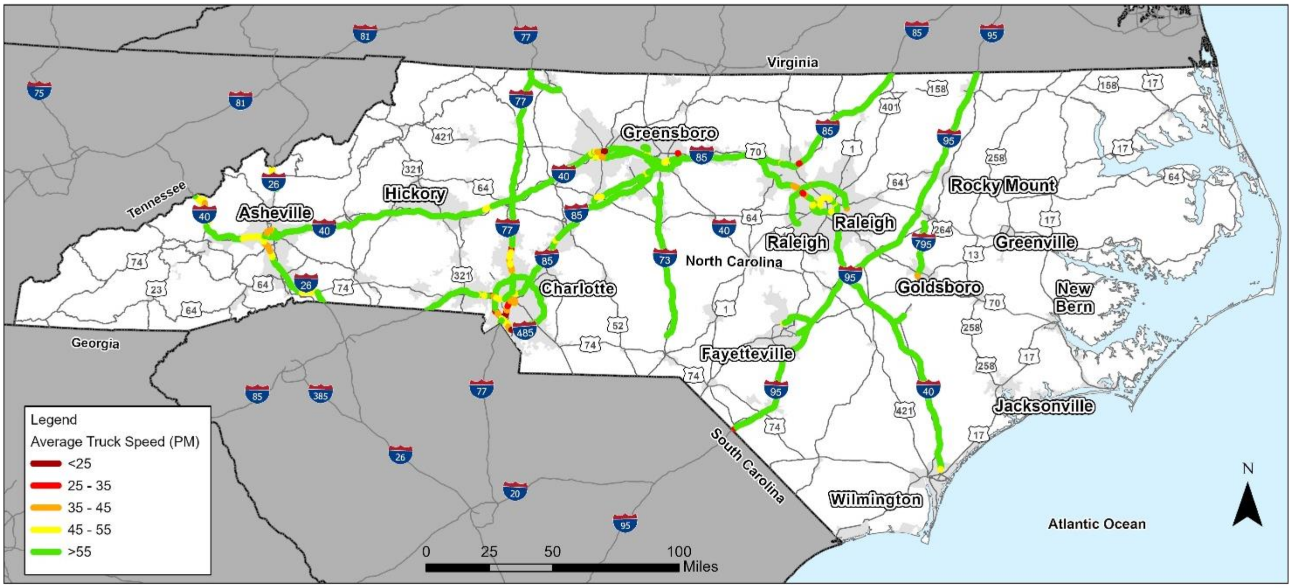
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.3 MIDDAY PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



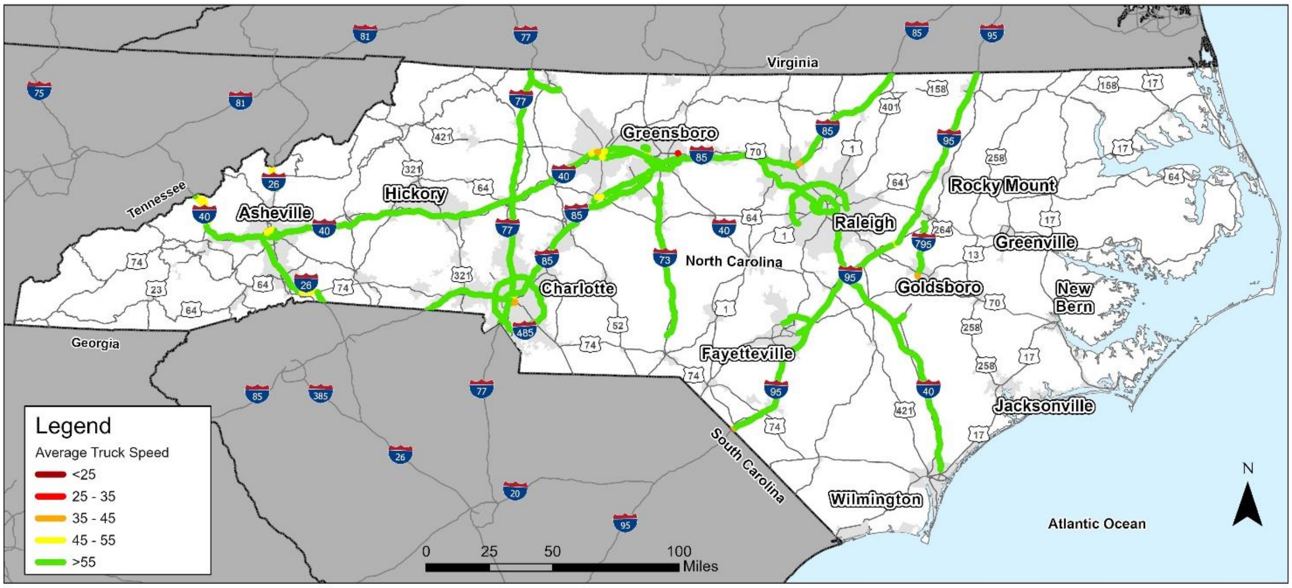
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.4 EVENING PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.5 OFF PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

4.2.2 Non-Interstate Highways

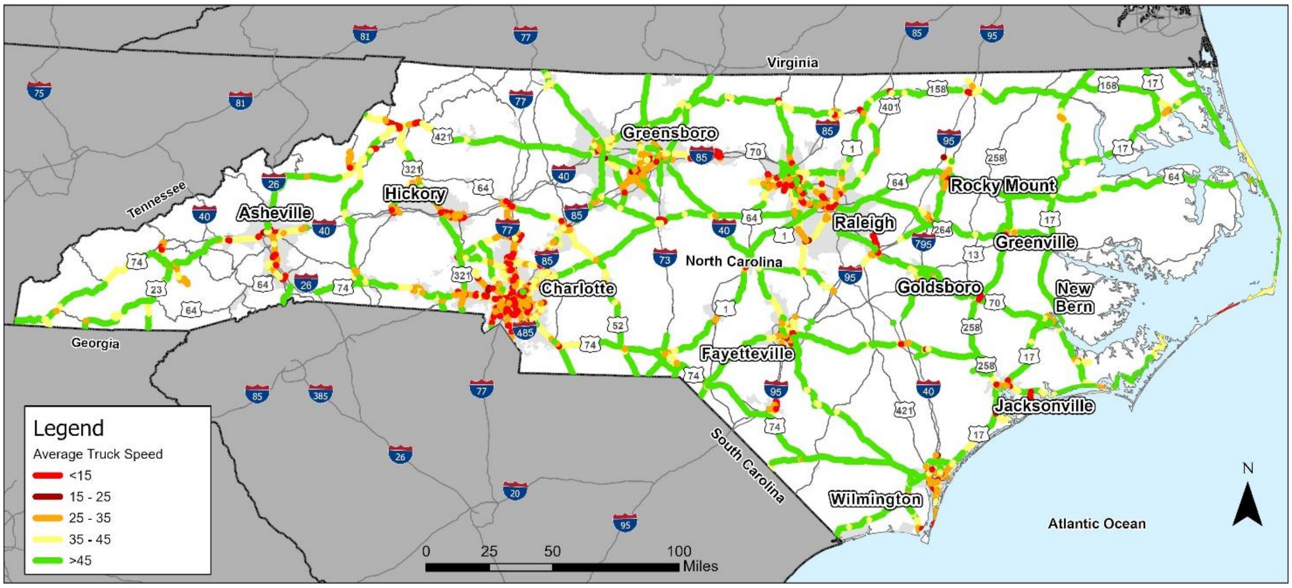
This portion of the truck congestion analysis uses 45 mph as the reference speed as opposed to 55 mph in the analysis of interstate highways. This reduction in speed to 45 mph is reflective of the non-interstate highways design speed being lower than that of interstate highways. Like the analysis of interstate highways, the results of non-interstate NHS route analysis indicates that lower truck speeds are mostly clustered within the state's largest metropolitan areas. NHS routes in the eastern and southern portions of the state generally exhibit higher speeds than elsewhere, reflecting the population distribution throughout the state. However, relatively slow speeds are exhibited throughout the system wherever these routes intersect communities across the state.

It is important to note that the NPMRDS travel time data includes the control delay experienced by vehicles at stop and signal-controlled intersections; therefore, the average speeds calculated for these facilities reflects that delay. In addition, motor carriers purposefully operate at slower speeds along local roads in the interest of safety, which is also reflected in the data. Figure 4.6 to

Figure 4.9 shows the average truck speeds on non-interstate highways for different time periods throughout the day.

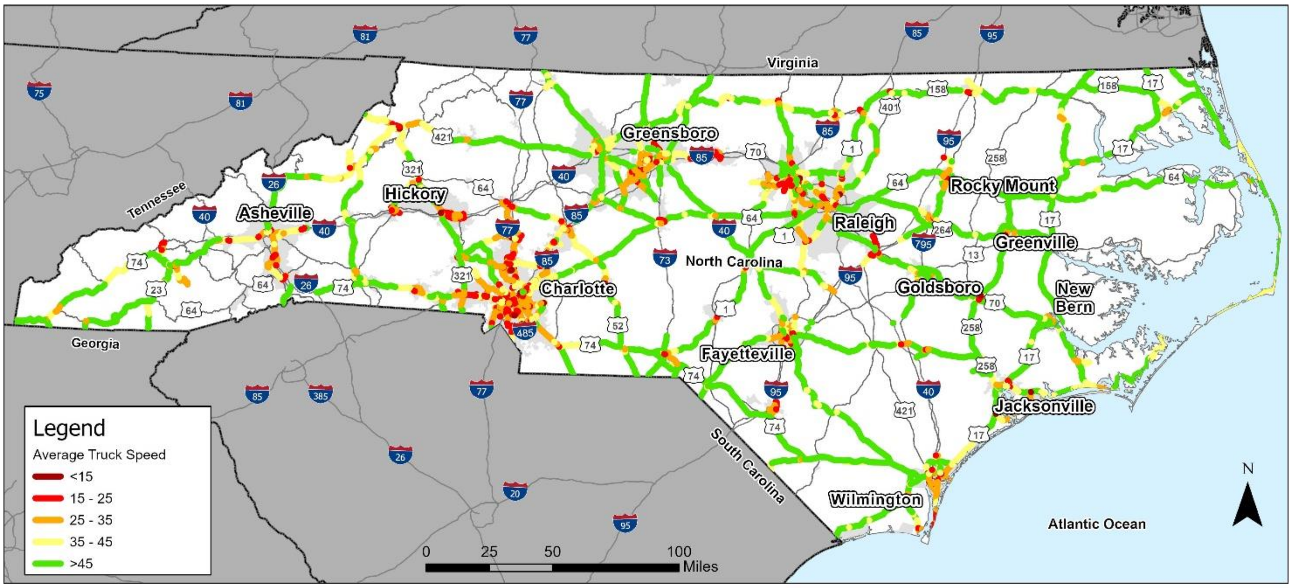
In general, facilities that have portions that are limited access (and to a lesser extent median-separated) exhibit less congestion than all others. For instance, U.S. 74 between Wilmington and Charlotte is largely a limited-access highway with relatively few grade-level intersections compared to its overall length. Similarly, U.S. 64 between Rocky Mount and Raleigh and U.S. 321 between Gastonia and Hickory are also largely limited access highways with high levels of service as indicated by average truck speeds.

FIGURE 4.6 MORNING PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



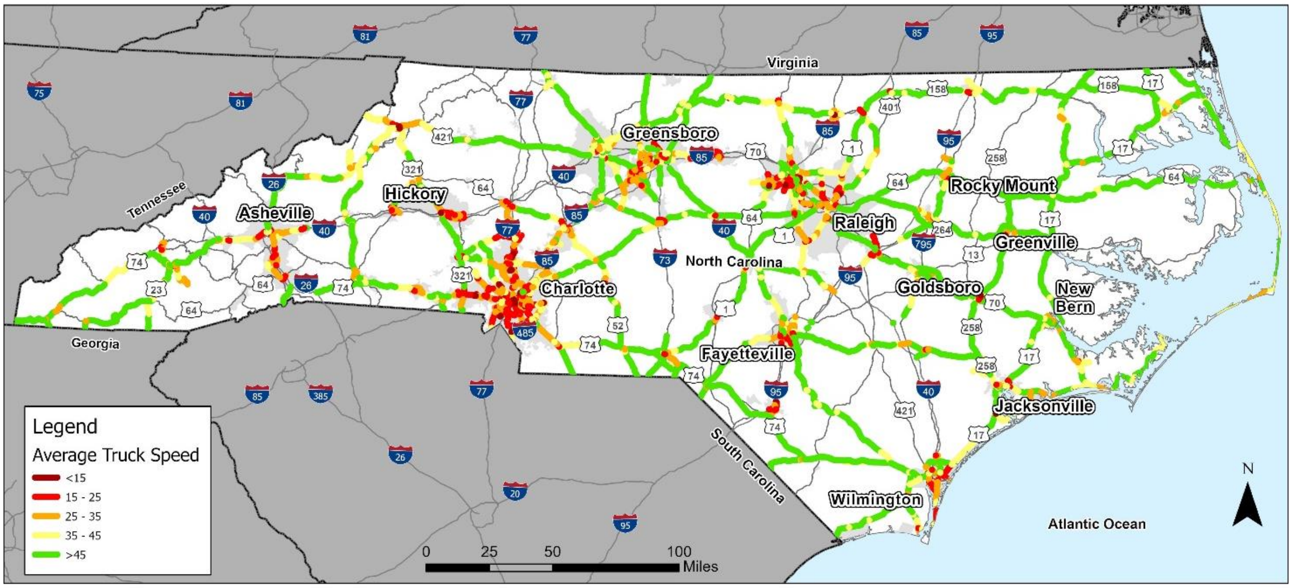
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.7 MIDDAY PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



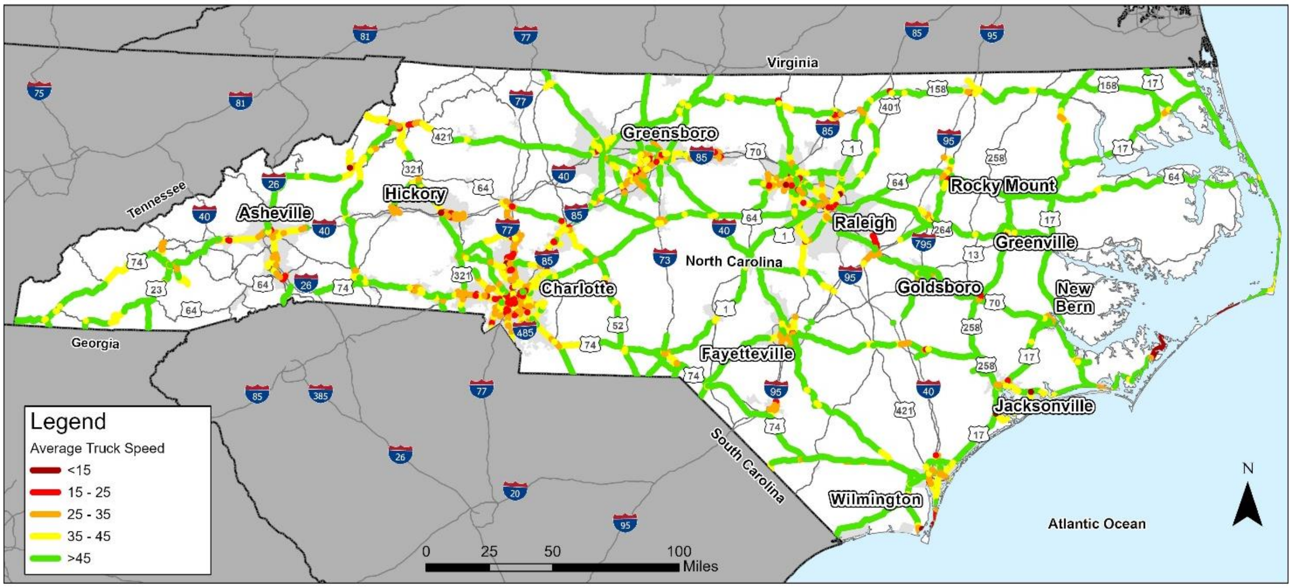
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.8 EVENING PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.9 OFF PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

4.3 Truck Travel Time Reliability

Reliability measures gauge the variability of travel times within peak periods. Roadway segments with highly variable travel times are deemed less reliable than those with more consistent travel times. Reliability is a particularly useful freight performance measure because it is directly related to a motor carrier's operating cost. Truck travel on less reliable routes compels carriers to build into their schedules extra time because they are unsure of the actual travel time any given trip on that route will require. This results in higher labor costs and missed opportunities to use a truck to carry an additional shipment.

This analysis measures reliability via the Buffer Time Index (BTI). The BTI is the ratio of the difference between the 95th percentile truck travel time and average travel time to the average travel time: (95th Percentile Travel Time – Average Travel Time) / Average Travel Time. Thus, the BTI represents the extra time (i.e., buffer) that must be factored into scheduling to ensure an on-time arrival for 95% of truck trips. A lower BTI indicates that expected travel delays are minimal and additional time may not be required to travel through that corridor. A higher BTI indicates the opposite; extra travel time is needed to traverse a corridor. For example, a BTI equal to 0.5 indicates that a trip on average takes 30 minutes would need 50% more time, or an extra 15 minutes, (for a total scheduled travel time of 45 minutes) to reach its destination on time with confidence. For this analysis, a BTI of 0.3 is used as the threshold for unreliable truck travel for both interstate and non-interstate highways.

4.3.1 Interstate Highways

As shown in Table 4.3, the reliability analysis indicates that overall, the interstate highway system in North Carolina appears to have reliable performance. The majority of the system (by mileage in both directions) exhibits buffer time indices less than or equal to 0.3. Approximately 91% of the state's system provides reliable truck travel during the morning peak. Performance improves during the midday period as 94% of the system has reliable truck travel times. The worst performance is observed during the evening peak period where 84% of the system provides reliable truck travel.

TABLE 4.3 SUMMARY OF TRUCK TRAVEL TIME RELIABILITY FOR INTERSTATE HIGHWAYS

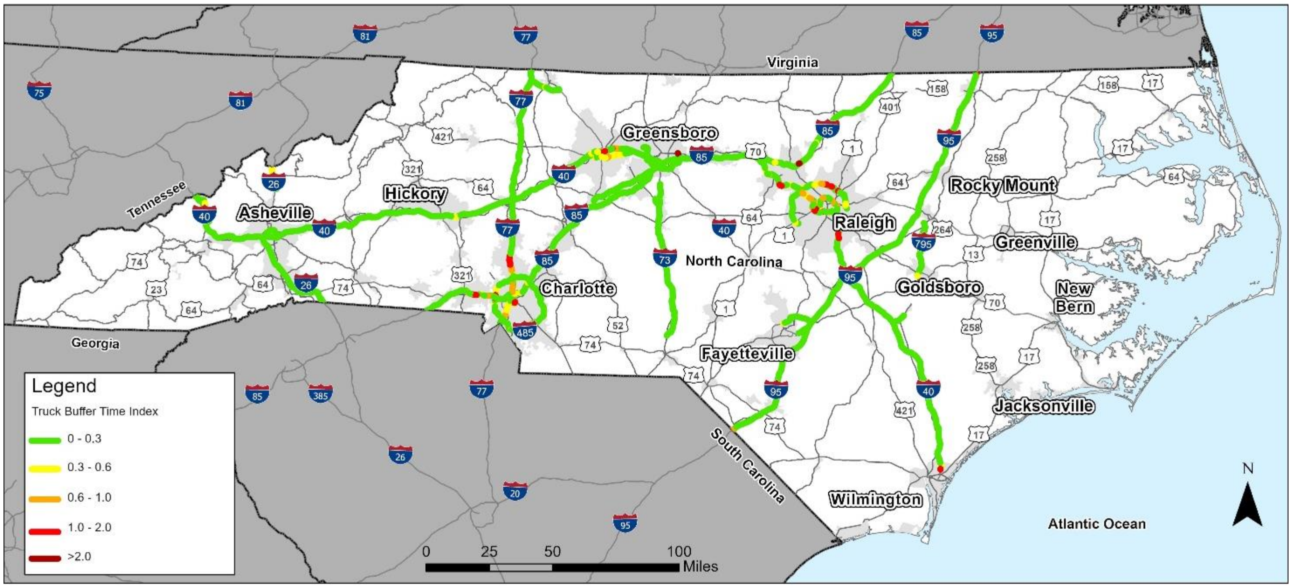
Peak Period	Total Mileage Reliable (Both Directions)	Percent of Total Mileage that is Reliable
Morning	2,330	91%
Midday	2,389	94%
Evening	2,134	84%
Off Peak	2,497	98%
Total Mileage (Both Directions)	**2,551**	**100%**

Source: 2019 National Performance Research Data Set; Consultant analysis.

Figure 4.10 to Figure 4.13 show the truck travel time reliability on North Carolina interstate highways for different time periods throughout the day. Similar to the truck congestion analysis, the truck travel time reliability analysis indicates poor reliability in the state's largest urban areas – the Charlotte, Triangle, and Triad Regions – along many of the same interstate highways previously identified. In the Triangle Region, poor travel time reliability is most pronounced along I-40 and I-440 through Raleigh. Along the I-40 corridor, poor reliability extends west from Raleigh to Durham and south towards the I-40/U.S. 70 interchange. Poor reliability is also exhibited along I-540 near its interchange with I-40 and N.C. 540. In the Charlotte Region, truck travel time reliability is poorest along I-77 through the core of the region and north of the I-485 perimeter. The southwest portion of I-485 (between U.S. 74 and I--85) and the northern portion of I-85 (from the I-485 perimeter to its interchange with U.S. 52 in Salisbury) also exhibit poor reliability. Truck travel time reliability is poorest in the Triad along the portion of I-40 bounded by U.S. 421 on the western side of Winston-Salem.

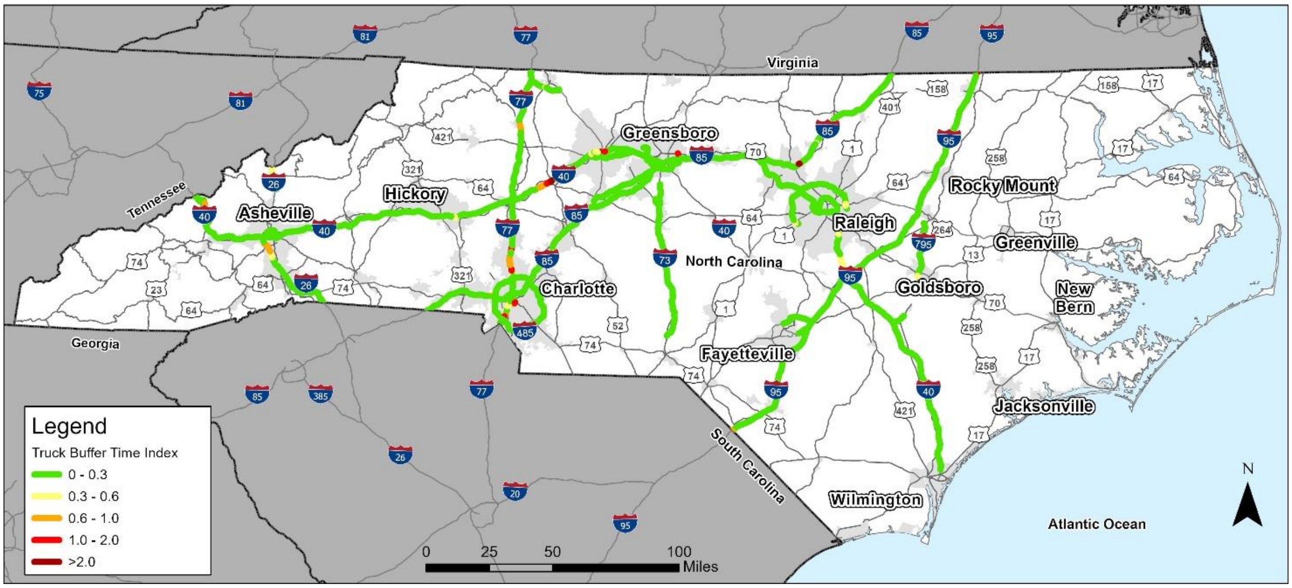
Outside of the larger metropolitan areas, poor reliability is also exhibited on key highways within the Asheville region. Poor truck travel time reliability in the Asheville region is primarily along I-240 and I-26 south of I-40.

FIGURE 4.10 MORNING PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



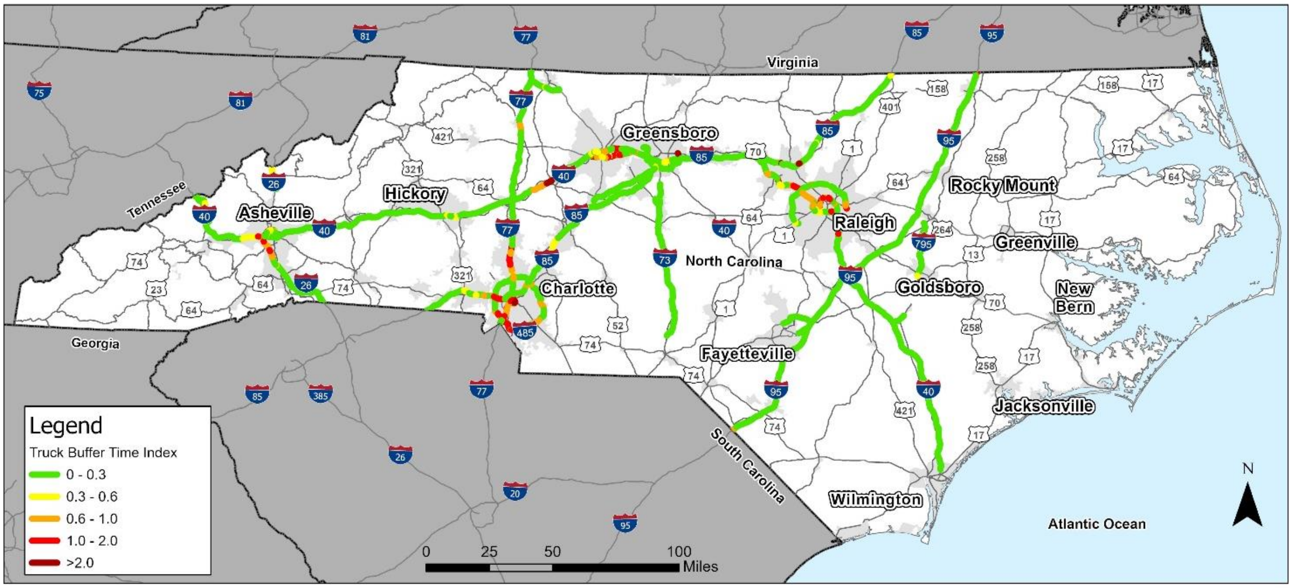
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.11 MIDDAY PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



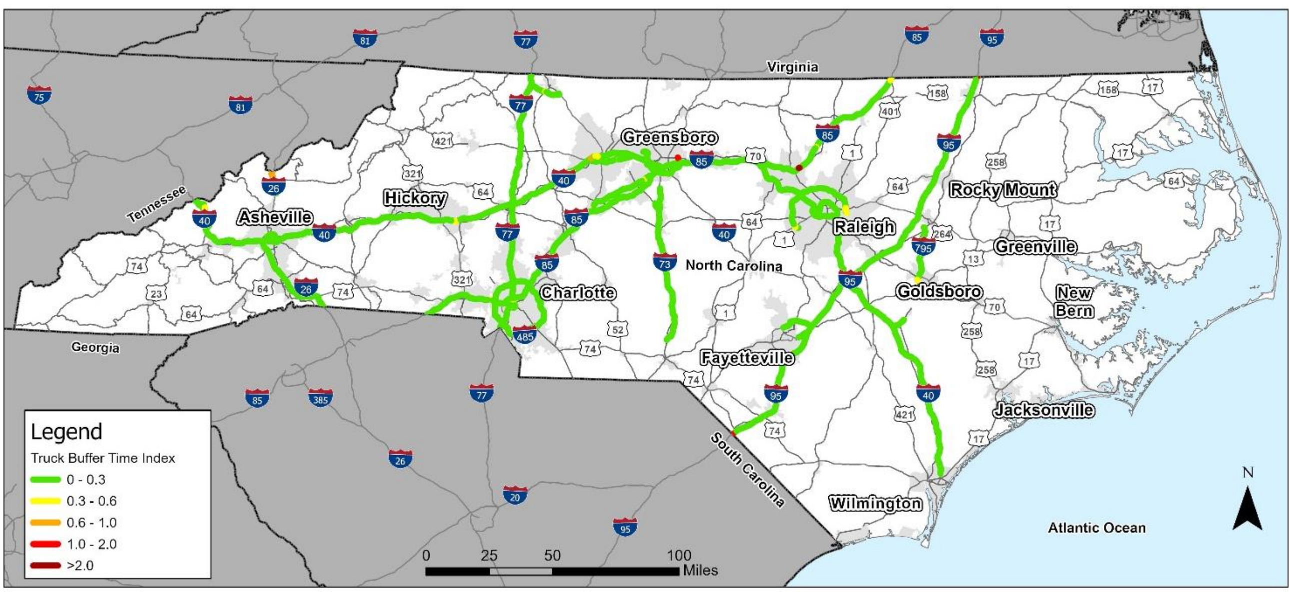
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.12 EVENING PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.13 OFF PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



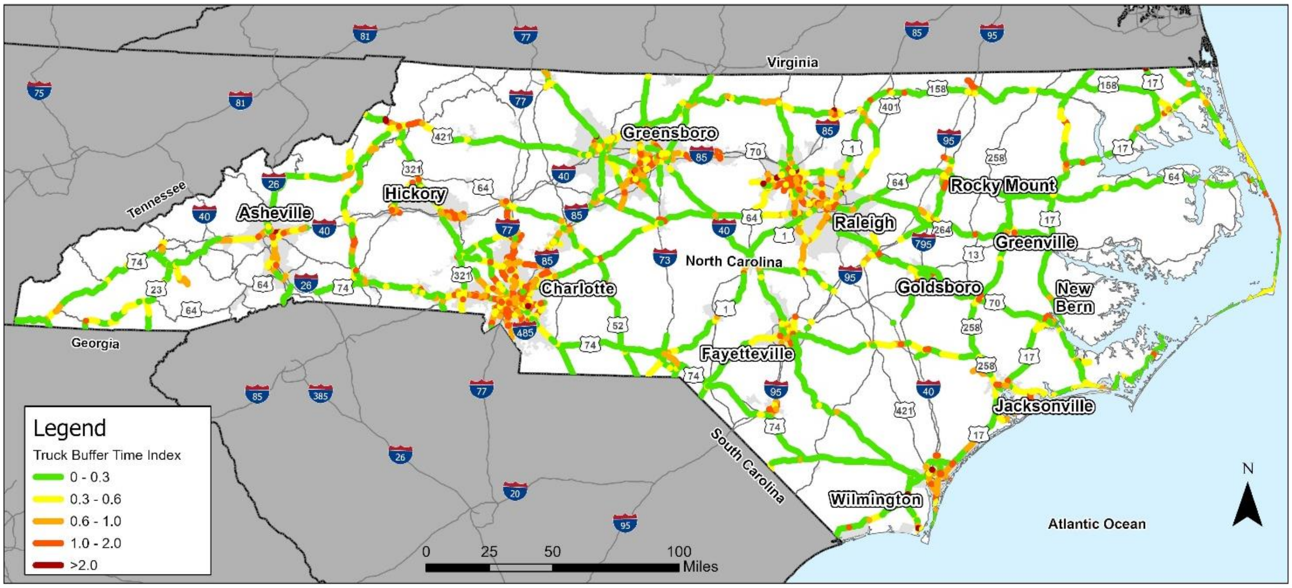
Source: 2019 National Performance Research Data Set; Consultant analysis.

4.3.2 Non-Interstate Highways

The analysis indicates less reliability on the state's non-interstate highways. In general, BTIs are much higher on these roadways as shown in Figure 4.14 through Figure 4.17. However, non-interstate routes are not designed to provide the same level of performance as interstate routes. Notably, non-interstate routes with portions that are limited access perform much better. For instance, U.S. 74 between Wilmington and

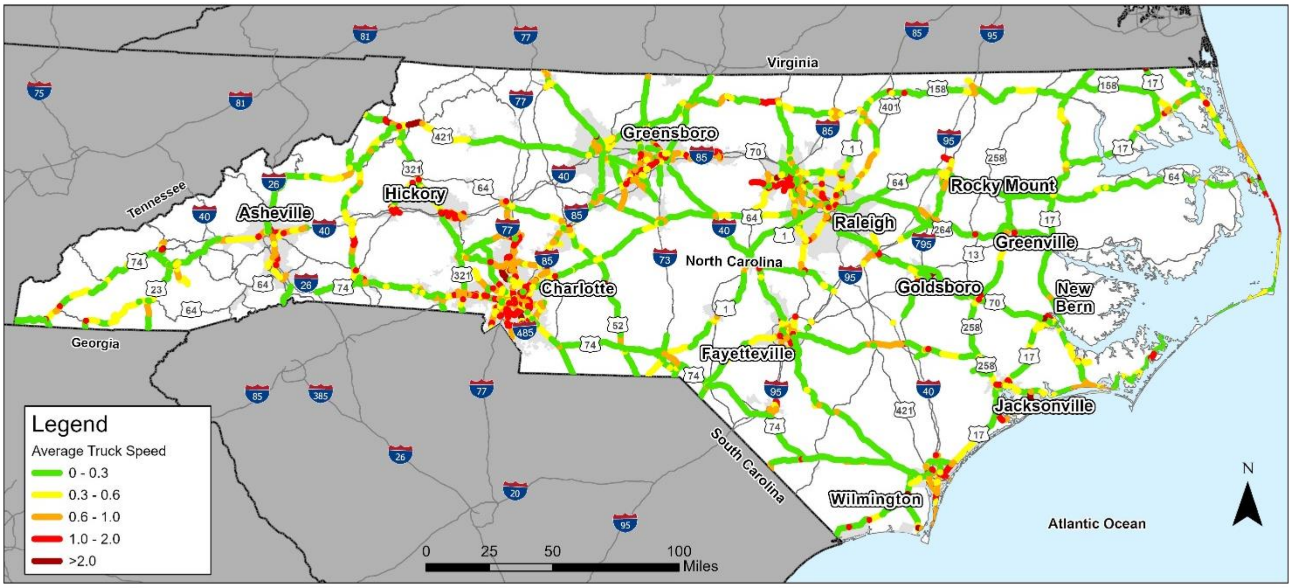
Charlotte provides a greater level of truck travel time reliability than other routes. The same is true of U.S. 64 and U.S. 264 east of Raleigh towards Rocky Mount and Greenville, respectively. Some of these highways will be upgraded to interstate highways. This is discussed is greater detail in Section 6.3.

FIGURE 4.14 MORNING PEAK TRUCK TRAVEL TIME RELIABILITY NON-INTERSTATE HIGHWAYS



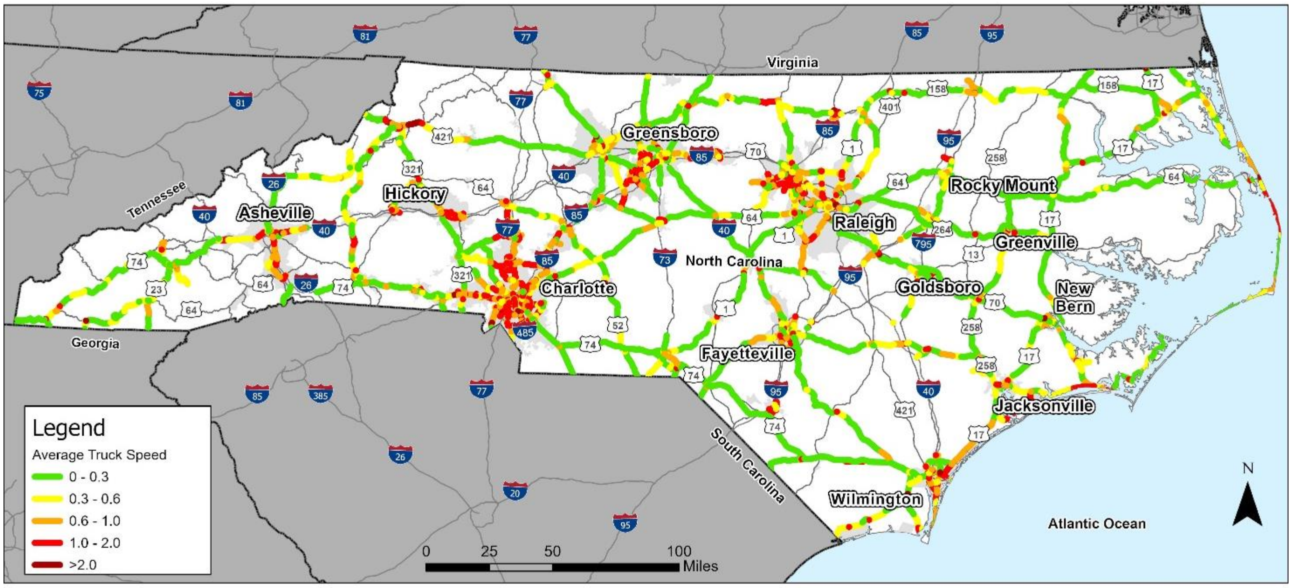
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.15 MIDDAY PEAK TRUCK TRAVEL TIME RELIABILITY NON-INTERSTATE HIGHWAYS



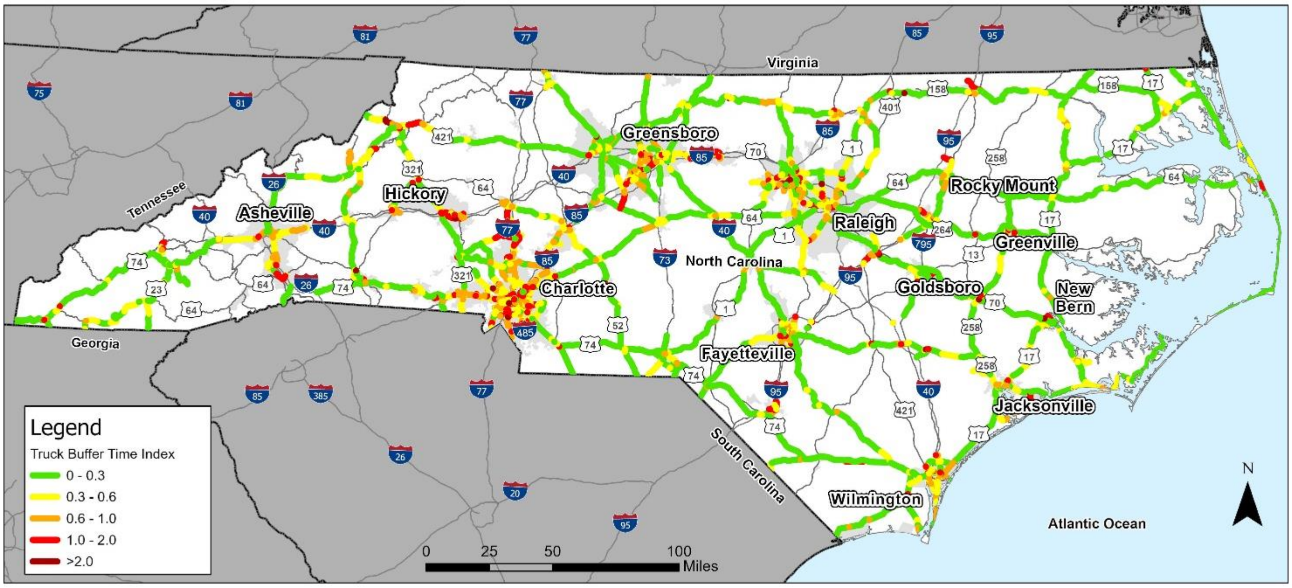
Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.16 EVENING PEAK TRUCK TRAVEL TIME RELIABILITY NON-INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

FIGURE 4.17 OFF PEAK TRUCK TRAVEL TIME RELIABILITY NON-INTERSTATE HIGHWAYS



Source: 2019 National Performance Research Data Set; Consultant analysis.

4.3.3 Truck Travel Sheds

Truck travel sheds represent the longest distance that trucks may be able to travel in all directions within a specified time window. In this manner, travel sheds can indicate the accessibility of various major U.S. economic markets to North Carolina shippers in one day of travel. For this analysis, time windows of 2, 4, 6, 8, and 10 hours were chosen since they are consistent with the distances that can be traveled within a single day (for 4 hours the driver can do a roundtrip). For each time window, various starting points representing North Carolina's major centers of economic and freight activity were selected. These include the cities of Charlotte, Raleigh, Greensboro, Wilmington, and Morehead City. For Rocky Mount, the travel sheds were adjusted to 30 minutes, 1 hour, 90 minutes, and 2 hours to approximate the market catchment area of the CSX terminal.

The cities of Charlotte, Raleigh, and Greensboro are at the core of the state's largest population and economic centers – the Charlotte , Triangle , and Triad regions, respectively. In addition, these areas contain the state's primary cargo carrying airports and rail intermodal terminals. Wilmington, Morehead City, and Rocky Mount all contain major freight terminals, namely the ports of Wilmington and Morehead City, and the CSX intermodal terminal at Rocky Mount. By selecting these regions, the analysis can explore the implications of congestion on supply chains for the primary nodes in the state's multimodal freight network.

Overall, the results indicate that markets from north Florida to eastern Pennsylvania along the Eastern Seaboard, as far west as Nashville in the southeast, and as far north as Cleveland in the Midwest represent the extent of the U.S. market within a day of travel. This footprint also contains several freight assets outside of North Carolina that are valuable to the state's shippers, such as the Ports of Jacksonville (FL), Savannah (GA), Charleston (SC) and Norfolk (VA). Decreasing congestion and increasing reliability on the state system would likely extend the reach of North Carolina's shippers and carriers, granting them greater access to the large northeastern consumer markets while maintaining access to growing areas in the southeastern U.S. like Atlanta and Nashville.

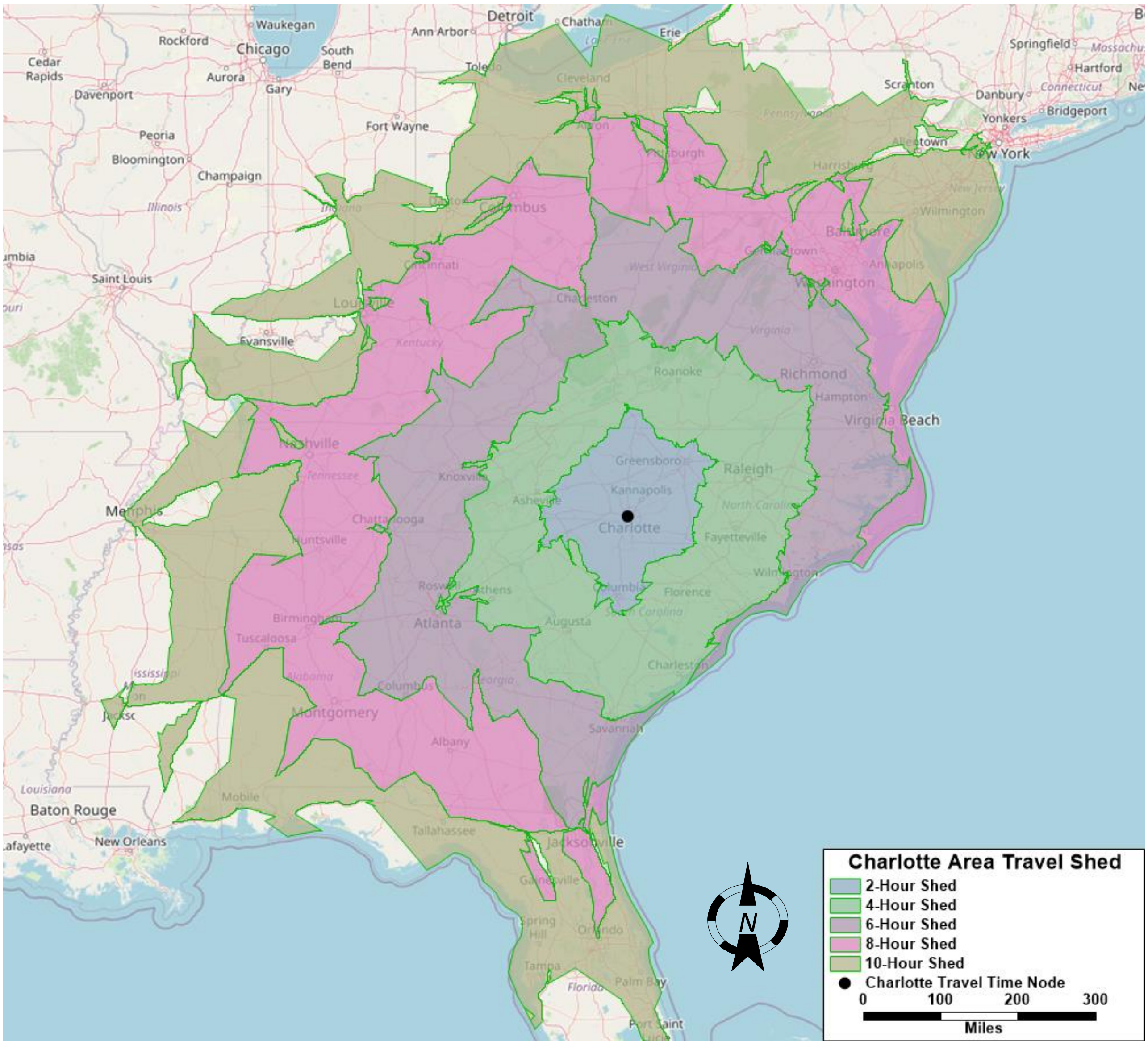
Charlotte Metropolitan Area

As shown in Figure 4.18, in a 4-hour time window, shippers based in Charlotte can access nearly all of North Carolina and South Carolina, but only the southwest portion of Virginia. This implies that with a half day of travel, motor carriers can reach major freight terminals such as the ports of Wilmington and Charleston, however, they cannot reach the Port of Morehead City. Also, within this 4-hour window, shippers and carriers cannot access the largest consumer markets in the southeastern U.S., including Atlanta, Nashville and Washington, D.C.

Shippers and carriers can reach as far south as Jacksonville, FL, as far west as Nashville, and as far north as Baltimore within an 8-hour time window. This indicates that the North Carolina economy is open to far more major markets via trucking within this time frame.

The 10-hour travel shed opens a few more markets to North Carolina via trucking. Those are primarily near the Great Lakes in the Midwest (e.g. Columbus, Cleveland, Cincinnati, and Indianapolis). In addition, markets in central Florida (e.g. Orlando) and in Pennsylvania (e.g. Philadelphia and Pittsburgh) are within reach.

FIGURE 4.18 TRAVEL SHED FOR THE CHARLOTTE METROPOLITAN AREA



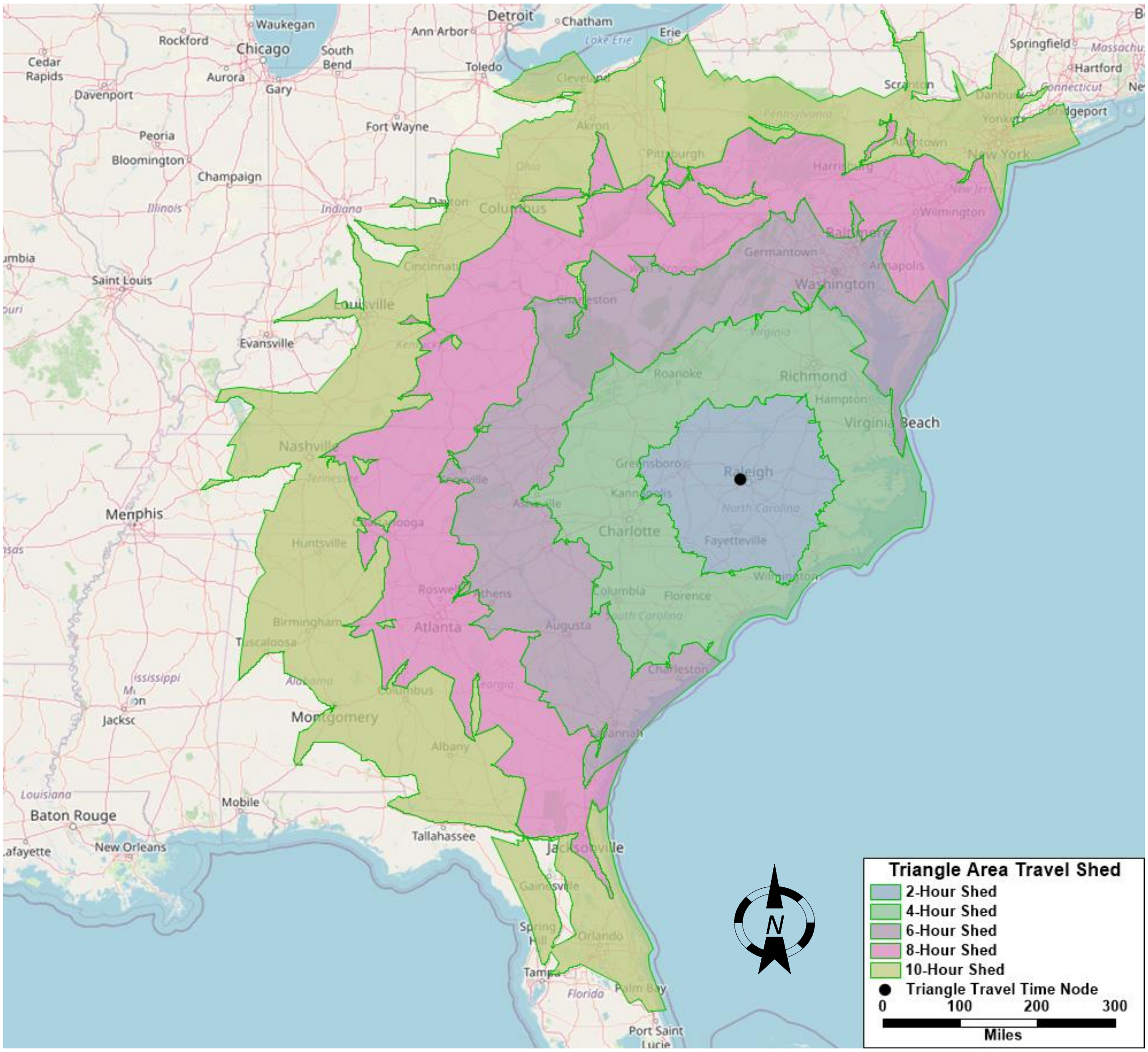
Source: NCDOT Travel Demand Model; Consultant analysis.

Triangle Region

Given its position in the central portion of the state, shippers and carriers in the Triangle Region can access much more of the northern stretches of the Eastern Seaboard by truck than those in the Charlotte Region (see Figure 4.19). Within a 4-hour time window, trucks originating in the Triangle Region can travel as far north as Fredericksburg, VA. This implies that in addition to the ports of Wilmington and Morehead City, shippers and carriers also have relatively easy access to the Port of Norfolk. However, trucks cannot reach the Port of Charleston like those originating in the Charlotte Region. Similar to the Charlotte Region, shippers and carriers in the Triangle Region cannot access the largest consumer markets in the southeast or northeast (e.g., Atlanta, Nashville, and Washington, D.C.) within this 4-hour window.

Shippers and carriers can reach as far south as Jacksonville, as far west as Atlanta, and as far north as Philadelphia, within an 8-hour time window. Within a 10-hour window, Nashville, and New York City are accessible as well. This places many of the largest consumer markets on the East Coast as well as numerous freight assets within reach of Triangle Region businesses within a day of travel.

FIGURE 4.19 TRUCK TRAVEL SHED FOR THE TRIANGLE REGION



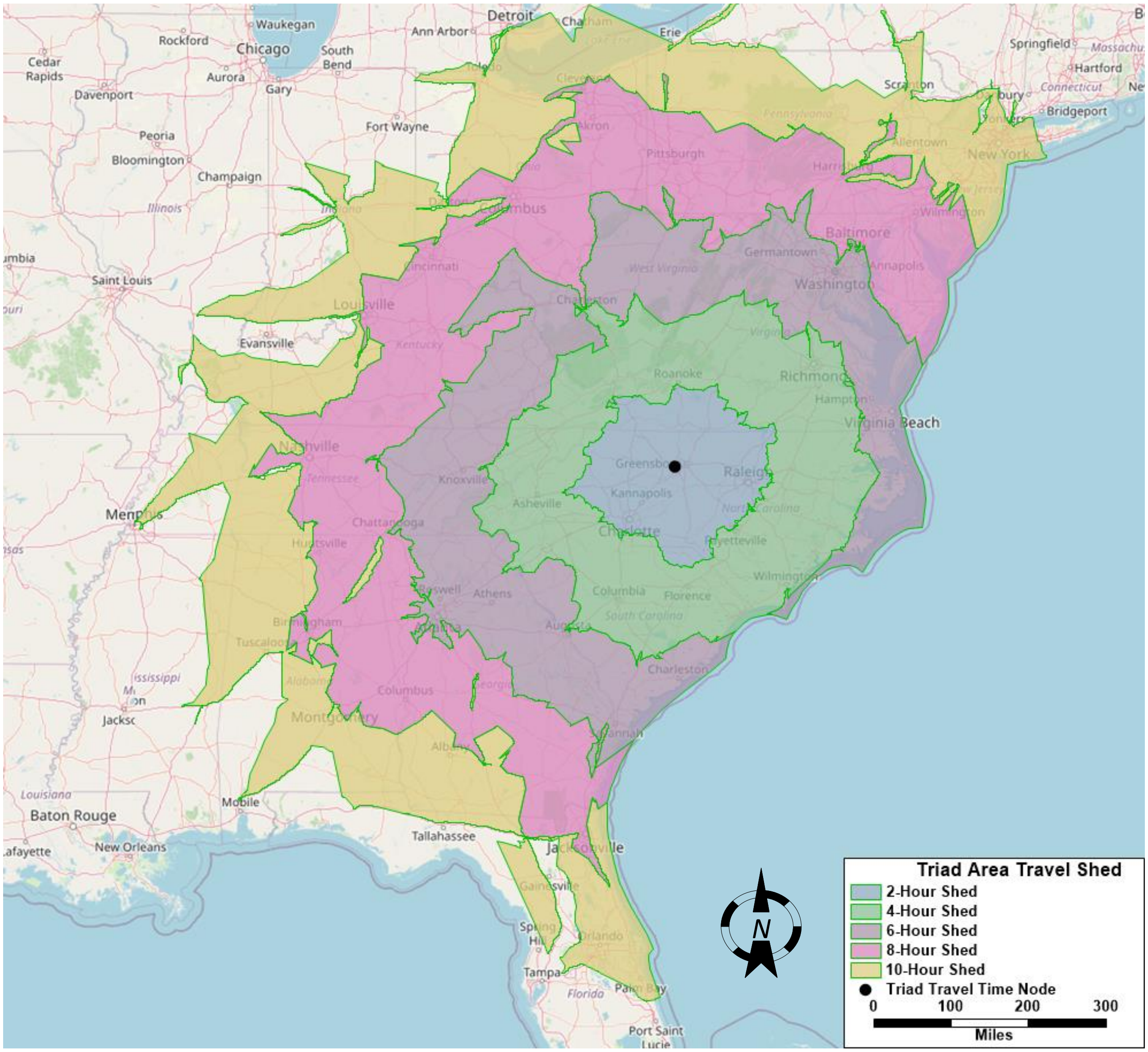
Source: NCDOT Travel Demand Model; Consultant analysis.

Triad Region

As shown in Figure 4.20, in a 4-hour time window, trucks originating in the Triad Region can access the ports of Wilmington and Morehead City, but not the ports of Norfolk and Charleston. In addition, shippers and carriers can reach all of North Carolina's largest cities as well as major metropolitan areas in Virginia, namely Hampton Roads and Richmond. Major metropolitan areas in Georgia and Tennessee cannot be reached during this time frame.

Shippers and carriers can reach as far south as Jacksonville, as far west as Nashville, and as far north as Baltimore within an 8-hour time window. Birmingham, New York, and major metropolitan areas near the Great Lakes in the Midwest (i.e., Columbus, Cleveland, Cincinnati, and Indianapolis) become accessible within a 10-hour travel shed.

FIGURE 4.20 TRUCK TRAVEL SHED FOR THE TRIAD REGION



Source: NCDOT Travel Demand Model; Consultant analysis.

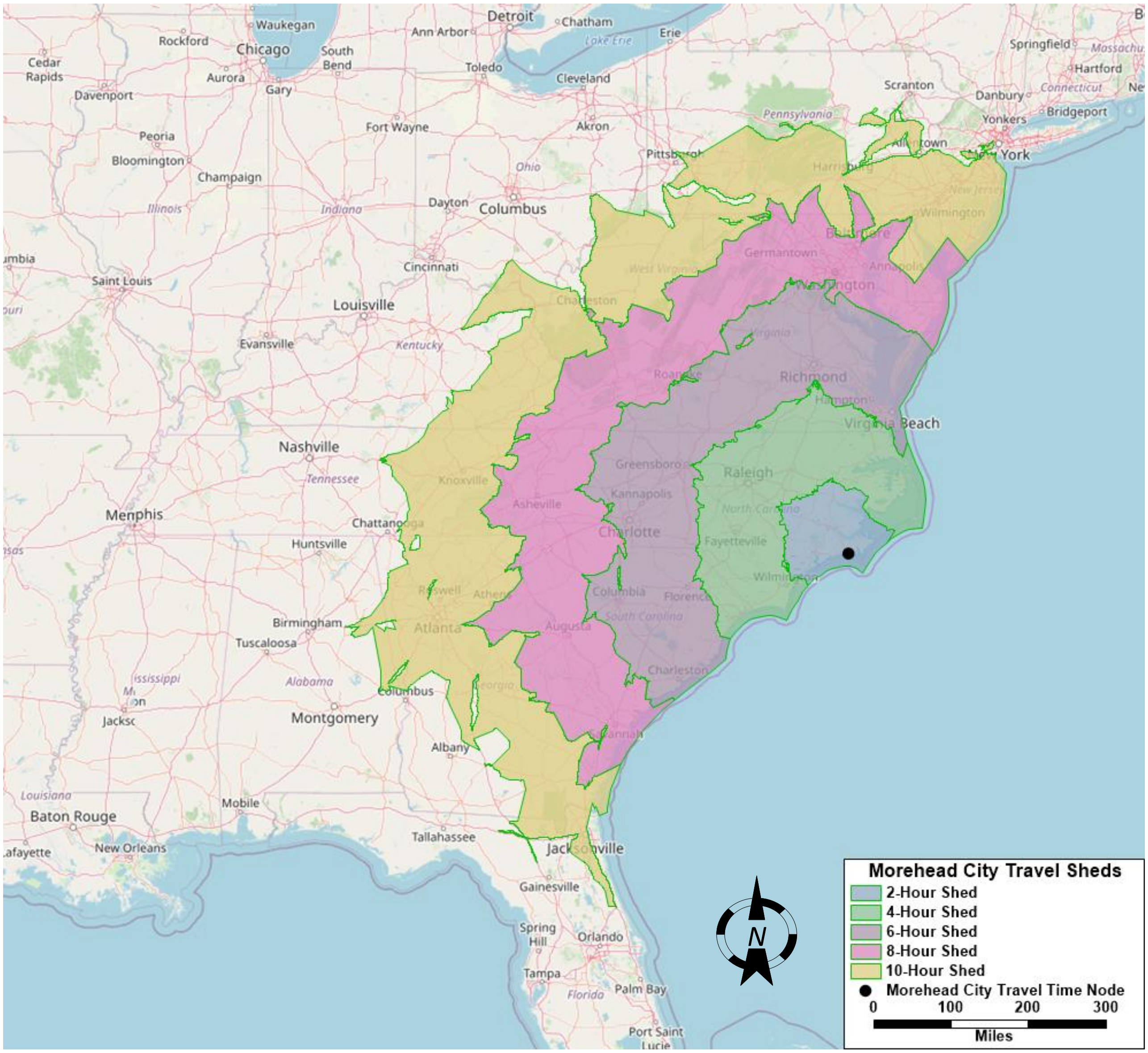
Morehead City

Morehead City has a relatively small 4-hour travel shed (see Figure 4.21). Within this time frame, trucks beginning in Morehead City cannot access the state's largest metropolitan region, Charlotte, nor any of the southeast's other major cities. This is a significant hindrance to the Port of Morehead City as its lack of accessibility limits its potential customer base.

The results of the 8-hour travel shed analysis are more encouraging as shippers and carriers can reach the entirety of North Carolina as well as Washington, D.C. and Baltimore. However, major southeastern markets such as Atlanta and Nashville cannot be accessed within the window. Those markets require a 10-hour time window.

None of the Great Lakes Region of the Midwest can be reached from Morehead City during any of the travel shed time windows. Midwestern markets are typically important customers for ports in the Southeast given their relative proximity. Increasing access to this region is important to making the Port of Morehead City a more competitive option for Midwestern shippers.

FIGURE 4.21 TRUCK TRAVEL SHED FOR THE PORT OF MOREHEAD CITY



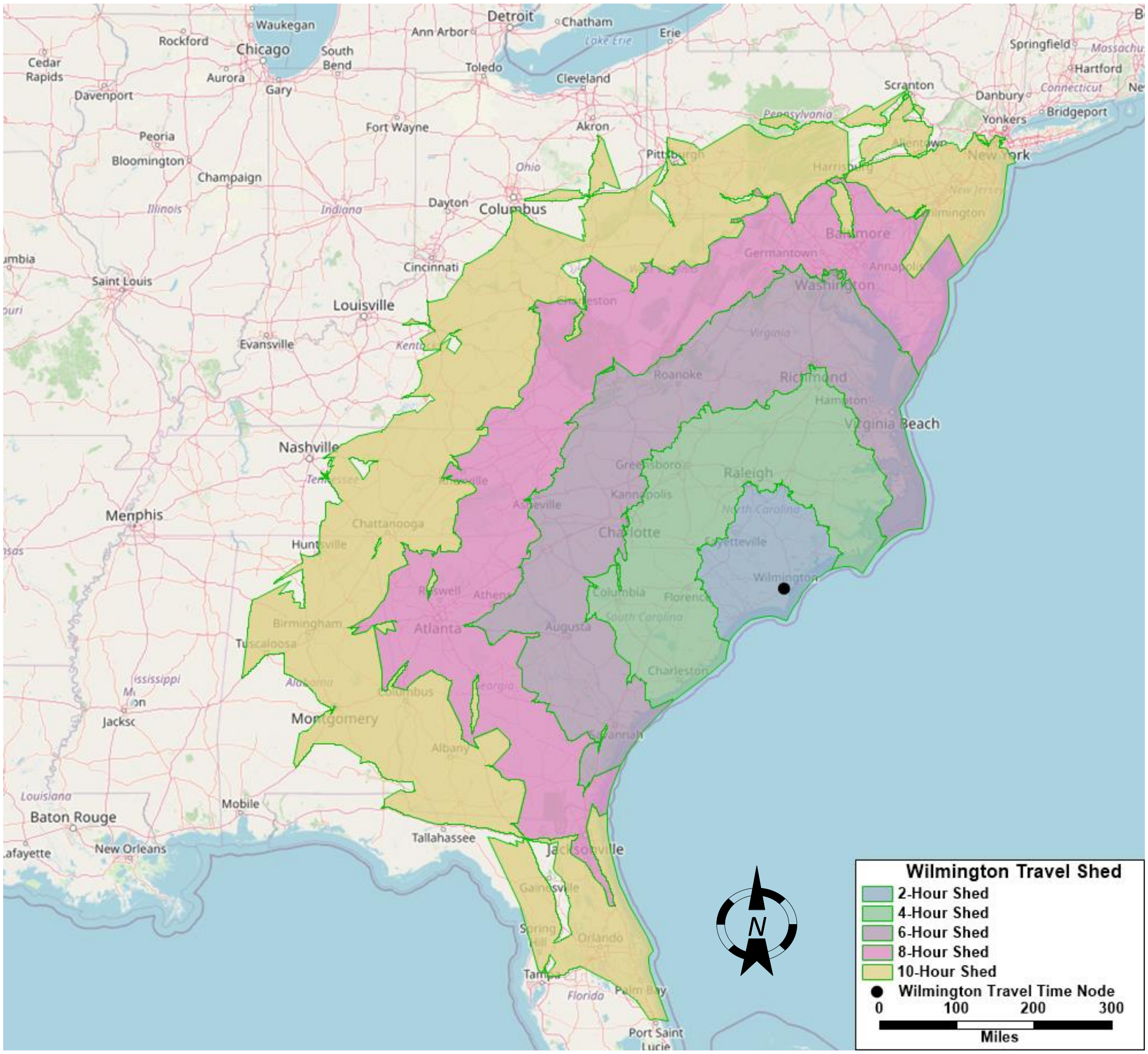
Source: NCDOT Travel Demand Model; Consultant analysis.

Wilmington

Similar to the Port of Morehead City, the Port of Wilmington has a relatively small 4-hour travel shed (see Figure 4.22). Within this time frame, trucks beginning in Wilmington can access the state's largest metropolitan region, Charlotte, but they cannot access any of the Southeast's other major cities – namely Nashville and Atlanta. Like the Port of Morehead City, this is a significant hindrance to the Port of Wilmington as its lack of accessibility limits its potential customer base. Furthermore, there are several other major container ports near the Port of Wilmington including Savannah, Charleston, and Norfolk.

Several more markets are accessible to the Port of Wilmington within an 8-hour travel shed. Shippers and carriers are able to reach the entirety of North Carolina as well as Washington, D.C., Baltimore, and Atlanta. However, none of the Great Lakes Region of the Midwest can be reached from Wilmington during any of the travel shed time windows. As mentioned before, Midwestern markets are typically important customers for Southeast ports given their relative proximity.

FIGURE 4.22 TRUCK TRAVEL SHED FOR THE PORT OF WILMINGTON



Source: NCDOT Travel Demand Model; Consultant analysis.

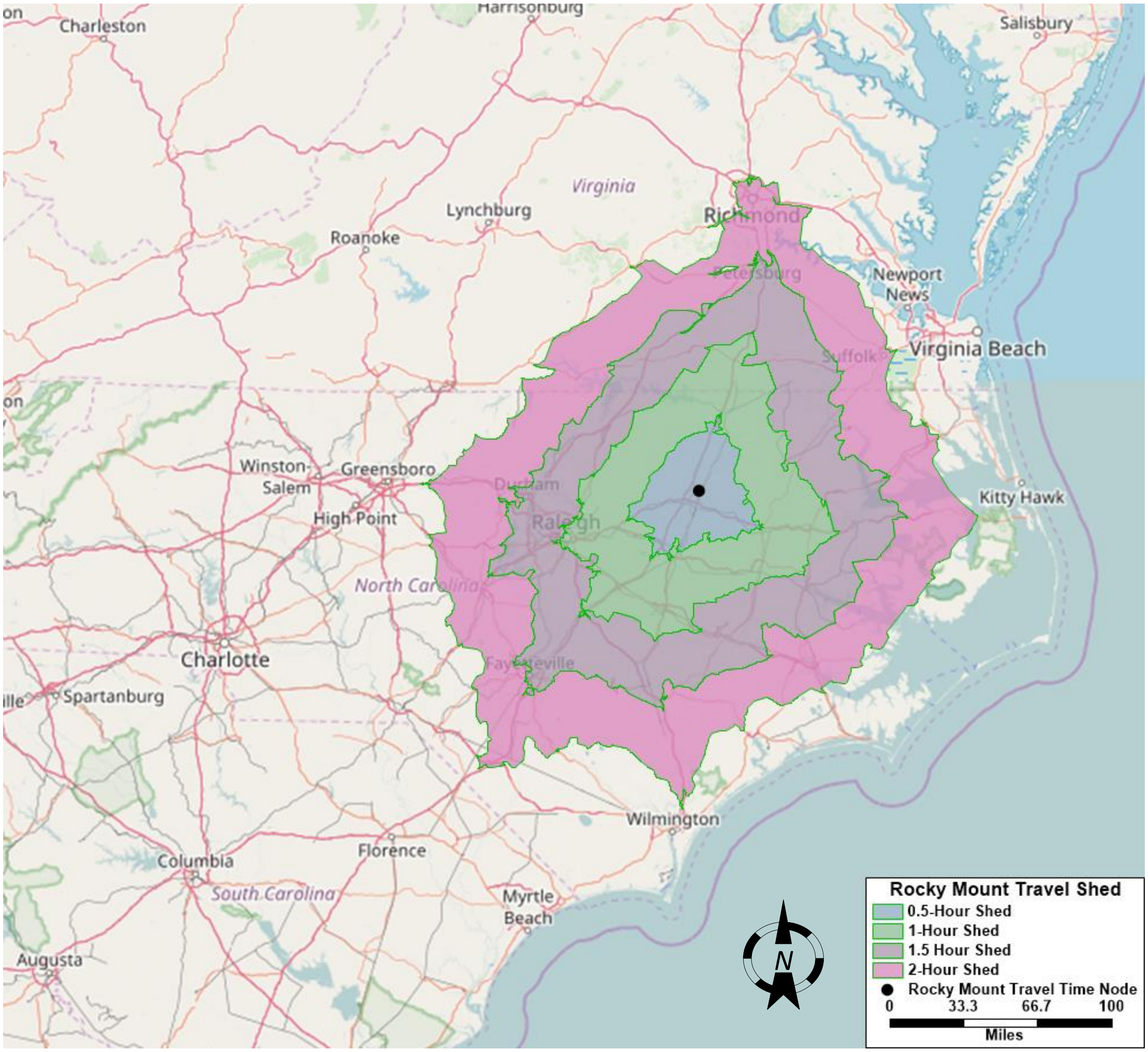
Rocky Mount

The CSX intermodal terminal at Rocky Mount opened in November 2021. The terminal increases North Carolina's access to the intermodal rail network and rail access to the Port of Wilmington. In addition, it is common for logistics companies to locate their facilities in proximity to major freight terminals such as intermodal yards. Given the potential of the development to increase truck-rail intermodal activity, it is important to examine truck travel sheds for this region of North Carolina. Due to the proximity of intermodal terminals in Charlotte and the Triad, as well as in Virginia and South Carolina, the travel times used in the market travel shed were reduced to 30 minutes, one hour, 90 minutes, and 2 hours (see Figure 4.23).

The completion of the terminal puts rail intermodal service within 2 hours of businesses located in Fayetteville to the south, southern Virginia to the north, the Triangle Region to the west and almost to

Morehead City to the east. The rail terminal acts as a hub in the CSX intermodal network meaning that trains come in, are split, and sent out to different markets. This increases the markets to which the eastern portion of North Carolina has rail access. However, most shippers rely on highway connectivity in and out of the terminal for the first and last mile service.

FIGURE 4.23 TRUCK TRAVEL SHED FOR THE ROCKY MOUNT CSX INTERMODAL TERMINAL

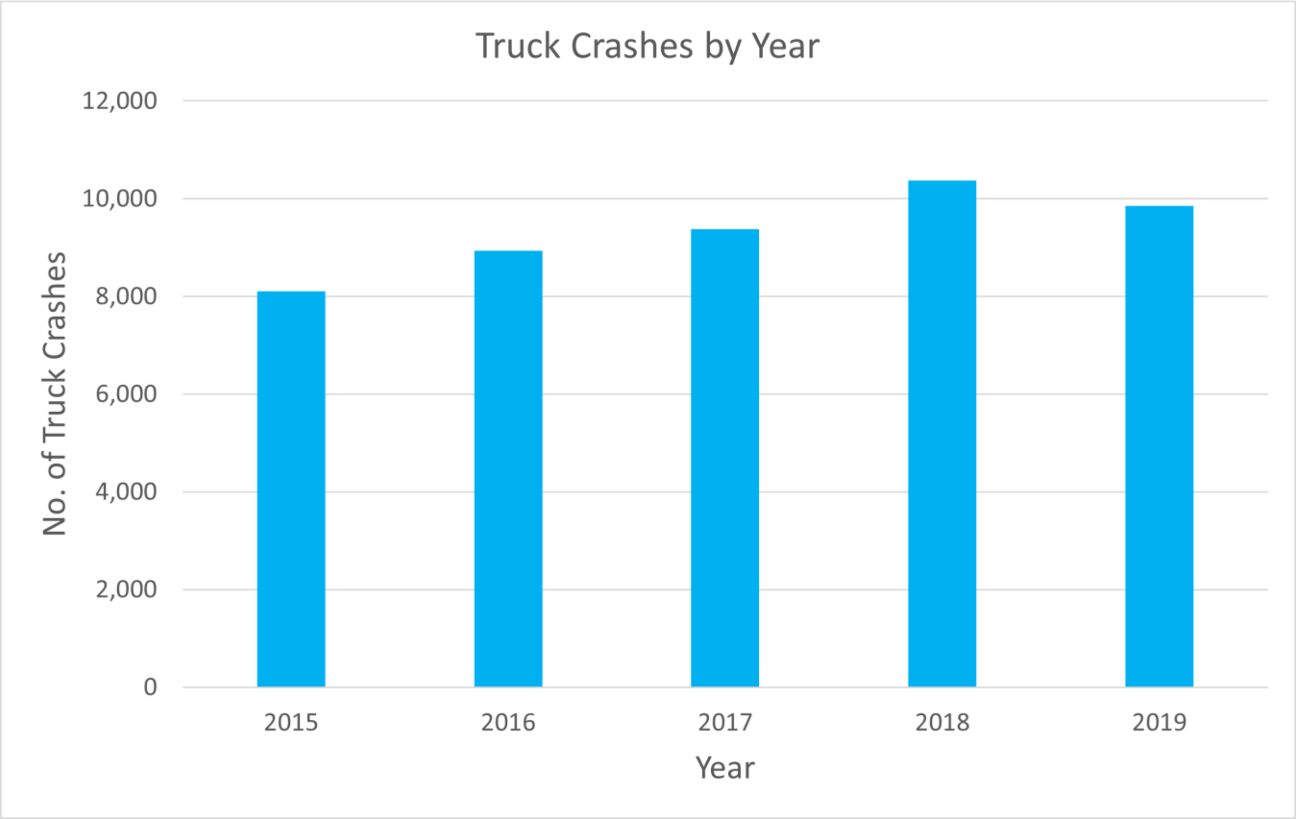


Source: NCDOT Travel Demand Model; Consultant analysis.

4.4 Truck Safety

Commercial vehicle crash data over the 2015 – 2019 time period was analyzed as part of this study. During this period, 46,630 truck-involved crashes occurred in the state with the total number of crashes increasing each year, except in 2019 (see Figure 4.24). As shown in Table 4.4, only ten counties accounted for nearly half of all truck crashes in the state over the 5-year period. All of the counties are located within one of the state's major metropolitan areas, namely the Charlotte, Triangle, Triad, Asheville and Fayetteville regions. Over 16% (7,507 crashes) of truck-involved crashes occurred in Mecklenburg County, the most in the state. Wake County had the next highest share of total truck crashes at just over 8% (3,520 crashes).

FIGURE 4.24 TRUCK CRASHES BY YEAR, 2015 - 2019



Source: North Carolina Department of Transportation; Consultant analysis.

Of the 46,630 truck-involved crashes that occurred in the state, about 71% (33,107) took place on the state-maintained roadway network. The remainder occurred on local roads or public areas. According to the 2019 NCDOT Annual Performance Report, the 5-year average of vehicle-miles traveled over the 2015 – 2019 time period was 1,136.74 100 million vehicle-miles traveled (100 MVM). Assuming this average is representative of the 2015 – 2019 time period, this results in a statewide crash rate of 49.2 truck crashes per 100 MVM.

TABLE 4.4 TOP TEN COUNTIES BY TRUCK CRASHES, 2015 - 2019

County	Number of Truck Crashes	Percent of Total
Mecklenburg	7,507	16%
Wake	3,520	8%
Guilford	2,302	5%
Forsyth	1,782	4%
Gaston	1,507	3%
Iredell	1,490	3%
Buncombe	1,315	3%
Cabarrus	1,271	3%
Durham	1,242	3%
Cumberland	1,143	2%
Subtotal	**23,079**	**49%**
Remainder of state	23,551	51%
Total	**46,630**	**100%**

Source: North Carolina Department of Transportation; Consultant analysis.

Regarding the severity of the truck crashes, just over 2% (1,127 crashes) were of the most severe injury outcomes (fatalities and incapacitating injuries) as shown in Table 4.5. Figure 4.25 displays the locations of these severe truck crashes throughout the state. Not surprisingly, they are distributed mostly along the state’s major highway routes and within its major metropolitan areas. The vast majority of truck-involved crashes (nearly 78% or 36,168 total crashes) resulted in no injuries.

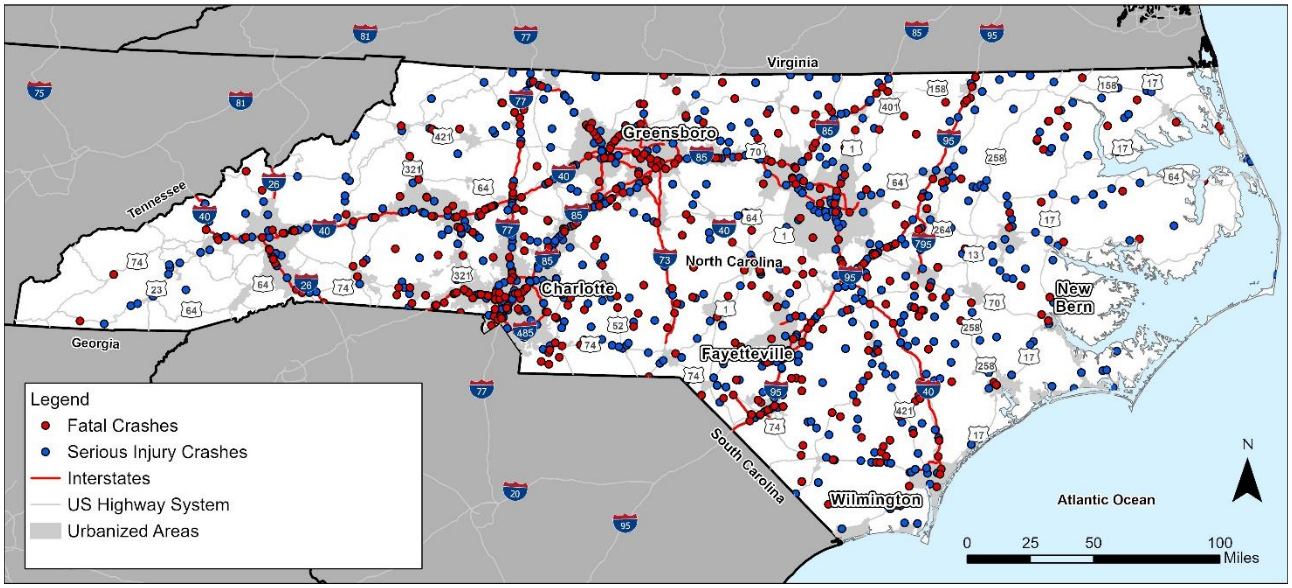
Certain types of crashes tend to have more severe outcomes than others. Crashes involving pedestrians or cyclists and those of the head-on or angle variety tend to result in fatalities or more serious injuries. According to the NC Division of Motor Vehicles (DMV) an angle collision is a result of vehicles hitting at or near right angles, with the front of one vehicle striking the side of the other vehicle. Table 4.6 presents a summary of truck crashes by type throughout the state. Head-on truck crashes comprised approximately 0.7% (328 crashes) of total crashes. Crashes involving pedestrians or cyclists comprised nearly 0.3% (146 crashes) of total crashes. A significant share of total truck crashes consisted of crash types that do not tend to result in serious injuries – namely sideswipes (32% or 14,871 crashes) and rear-end crashes (18% or 8,518 crashes).

TABLE 4.5 TRUCK CRASHES BY SEVERITY, 2015 - 2019

Crash Severity	Number of Truck Crashes	Percent of Total
Fatality	451	1.0%
Incapacitating Injury	676	1.4%
Non-Incapacitating Injury	2,825	6.1%
Possible Injury	6,540	14.0%
Property Damage Only and Unknown	36,168	77.5%
Total	**46,630**	**100%**

Source: *North Carolina Department of Transportation; Consultant analysis.*

FIGURE 4.25 SEVERE TRUCK CRASHES IN NORTH CAROLINA, 2015 – 2019



Source: *North Carolina Department of Transportation; Consultant analysis.*

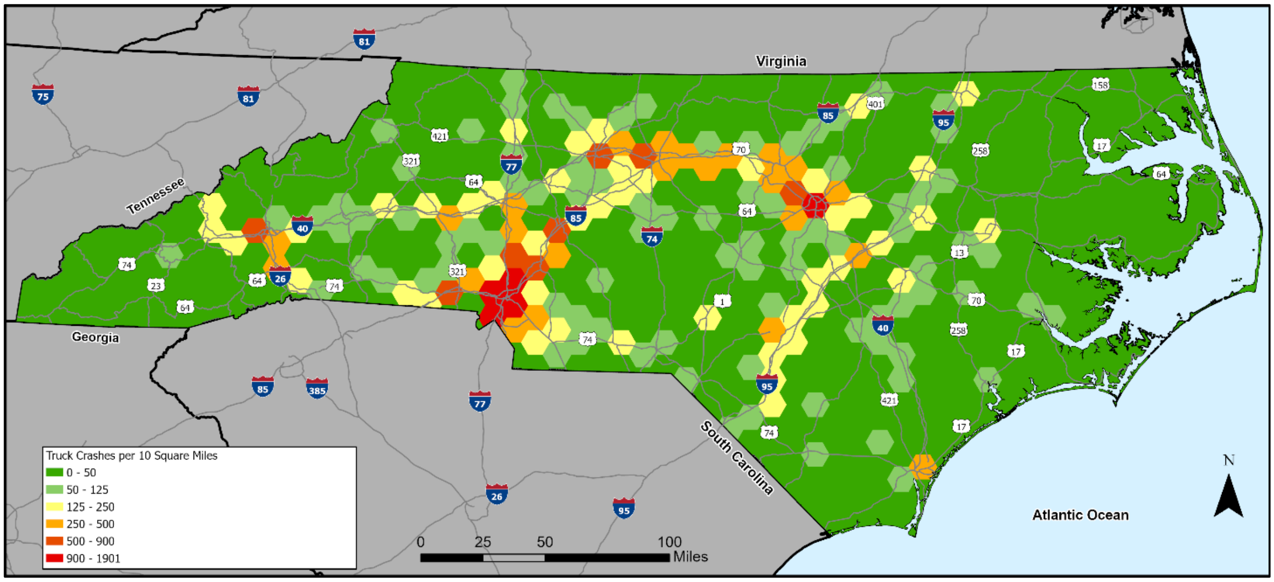
TABLE 4.6 TRUCK CRASHES BY TYPE, 2015-2019

Crash Type	Number of Truck Crashes	Percent of Total
Head On	328	0.7%
Pedestrians and Cyclists	146	0.3%
Angle	8,061	17.3%
Jackknife	288	0.6%
Ran Off Road	7,099	15.2%
Rear End	8,518	18.3%
Sideswipe	14,871	31.9%
All Others	7,319	15.7%
Total	**46,630**	**100%**

Source: *North Carolina Department of Transportation; Consultant analysis.*

A heat map of truck crashes is developed by calculating the density of crashes per 10 square miles (see Figure 4.26). The analysis indicates that crashes are clustered along North Carolina's primary freight highway corridors: I-85, I-40, I-77, and I-95. As stated previously, truck crashes are also clustered within the state's major metropolitan areas. In both cases, the clustering of truck crashes along the routes and within the regions identified are likely due to greater truck activity at those locations relative to other areas of the state.

FIGURE 4.26 TRUCK CRASH HEAT MAP, 2015-2019



Source: North Carolina Department of Transportation; Consultant analysis.

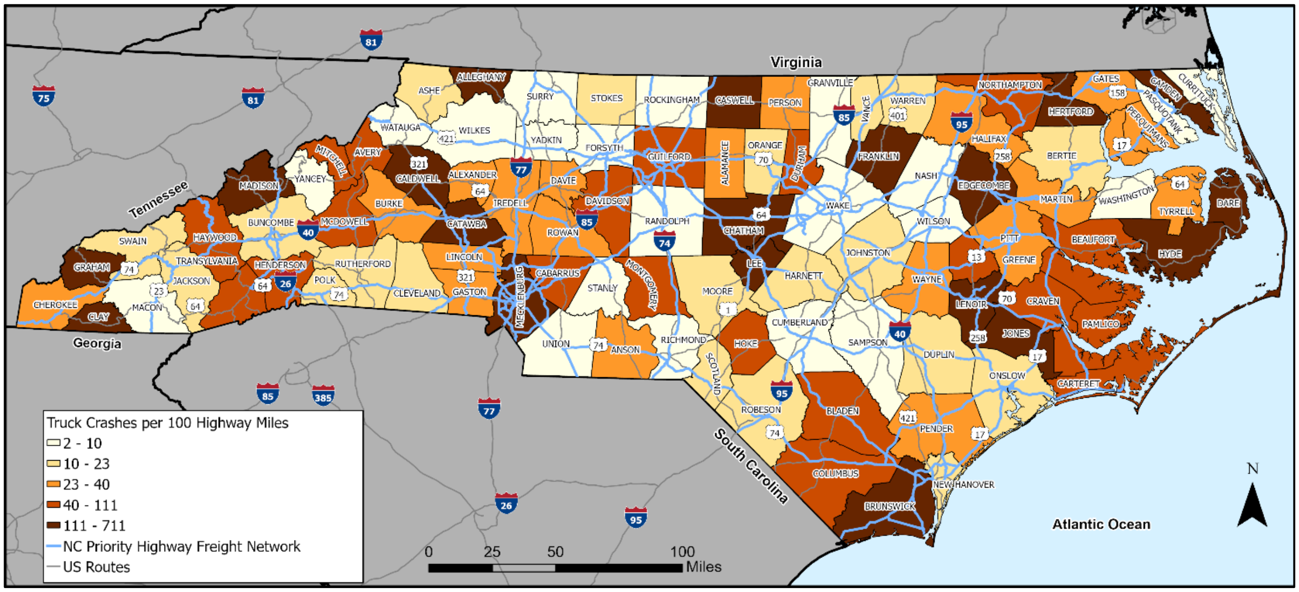
The analysis also examines truck crash rates by roadway mileage at the county level. Total truck crash rates are calculated as the number of truck-involved crashes within a county over the 2015 – 2019 time period divided by that county's total highway miles. Table 4.7 presents the top ten counties by truck crash rate in North Carolina. Figure 4.27 shows the truck crash rate per 100 miles of highway statewide.

TABLE 4.7 TOP TEN COUNTIES BY TRUCK CRASH RATE (HIGHWAY MILES BASED), 2015-2019

County	Total Truck Crashes per 100 Highway Miles
Mecklenburg	762
Forsyth	183
Durham	166
Cabarrus	156
Gaston	154
Wake	146
Guilford	123
Haywood	107
Buncombe	106
Iredell	96

Source: North Carolina Department of Transportation; Consultant analysis.

FIGURE 4.27 TRUCK CRASHES PER 100 HIGHWAY MILES, 2015-2019



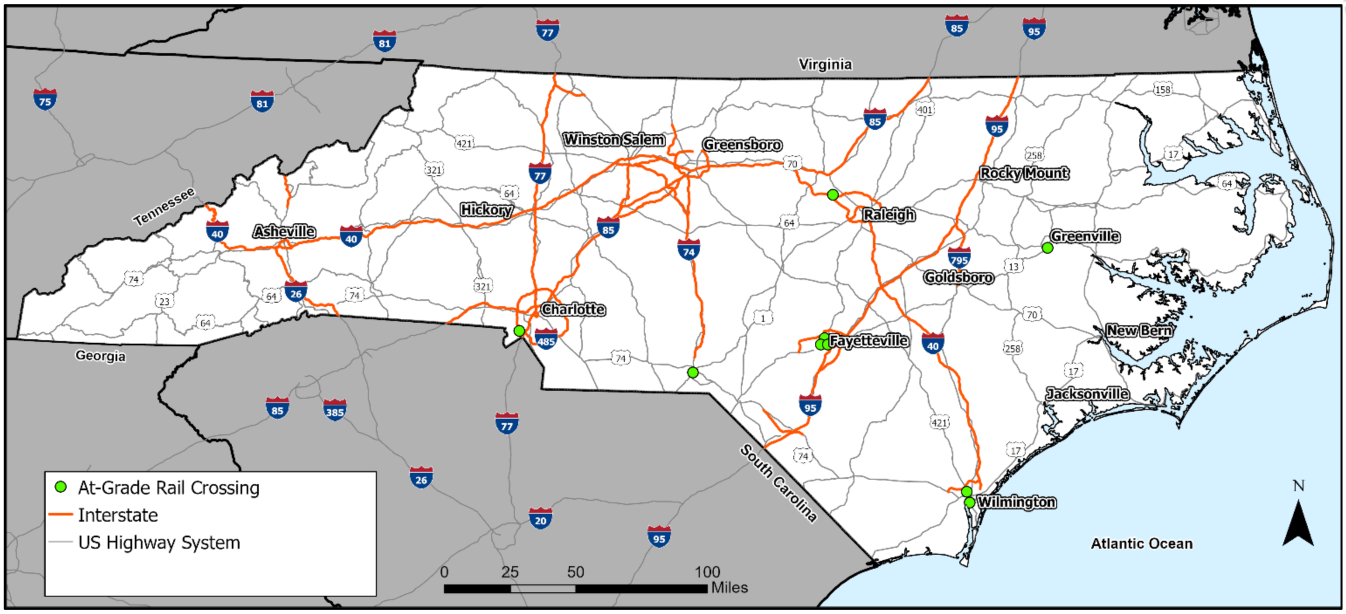
Source: North Carolina Department of Transportation; Consultant analysis.

4.5 At-Grade Rail Crossings

At-Grade rail crossings have the potential to impose significant delays to trucks as they wait for trains to pass. In addition, trucks idling at crossings emit more pollutants, particularly when they accelerate from a complete stop. Using the 2019 AADTT, the top 10 busiest crossings are shown and identified in Figure 4.28 and Table 4.8. Though at-grade crossings are scattered across the state, they are generally located east of I-77. Truck volumes at the top ten at-grade crossings range from approximately 2,000 to 3,000 trucks per day.

Most of the top ten at-grade rail crossings are located in urban portions of the state. The cities of Fayetteville and Wilmington have among the busiest rail crossings by daily trucks with a combined five of the top ten locations. The busiest rail crossing in the state, by AADTT, is in Rockingham on U.S. 1 with over 3,300 trucks per day. The at-grade crossing located on N.C. 160 in Charlotte carries nearly 2,800 trucks per day.

FIGURE 4.28 TOP TEN AT-GRADE RAIL CROSSINGS BY AADTT, 2019



Source: North Carolina Department of Transportation; Consultant analysis.

TABLE 4.8 TOP TEN AT-GRADE CROSSINGS BY AADTT, 2019

Rank	AADTT	Roadway	City
1	3,320	U.S. 1	Rockingham
2	3,170	U.S. 17	Wilmington
3	3,020	U.S. 421	Wilmington
4	2,780	N.C. 160	Charlotte
5	2,660	U.S. 401	Fayetteville
6	2,250	U.S. 1	Aberdeen
7	2,160	U.S. 301	Fayetteville
8	2,140	U.S. 264	Greenville
9	2,040	U.S. 401	Fayetteville
10	1,970	S. Miami Blvd.	Durham

Source: NCDOT Rail Division Data Second Quarter 2022 Release and NCDOT Traffic Survey Group Traffic Data Event Shapefile 2019 https://connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx.

Note: NC 160 and S. Miami Blvd. are not on the NC Priority Freight Network

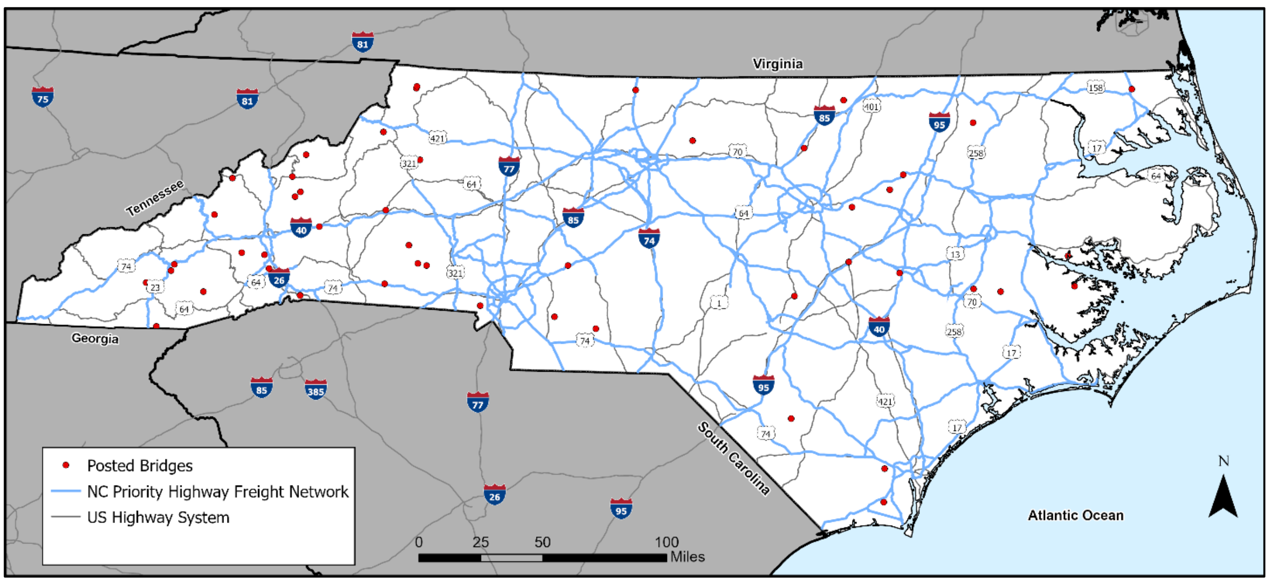
4.6 Condition of Bridges and Pavement

The condition of bridges and pavement can have significant impacts on the movement of freight across North Carolina. Bridges often represent chokepoints as those with insufficient weight limits or low clearances can force trucks onto routes that are more circuitous and result in longer travel times. Similarly, poor pavement conditions negatively impact the flow of freight across the state system as rough or cracking pavements can result in increased maintenance and reduced fuel economy for trucks. Strained pavement can also result in slower travel times as vehicles decrease their rate of speed to navigate potholes, debris or other road hazards that result from poor pavement conditions. This section of the report examines bridge and pavement conditions throughout the state.

4.6.1 Bridges

Based on their operating abilities, there are three different types of bridges that pose a challenge to statewide freight movements: posted , structurally deficient , and functionally obsolete bridges. Posted bridges are those whose structural load carrying capacity is limited to the weight of vehicles posted on the bridge. Bridge weight limits can hinder freight movements by reducing payload capacity of trucks using the route. As a result, trucks are sometimes forced to use longer routes that increase travel times and costs. Posted bridges on the state system are shown in Figure 4.29. As shown in Table 4.9, the most posted bridges are located in the western portion of the state in NCDOT Divisions 13 and 14. Collectively, the counties comprising these Divisions have 18 posted bridges (about 37%).

FIGURE 4.29 POSTED BRIDGES IN NORTH CAROLINA, 2022



Source: North Carolina Department of Transportation.

TABLE 4.9 POSTED BRIDGES BY NCDOT HIGHWAY DIVISION, 2022

Highway Division	Number of Posted Bridges	Percent of Total
1	1	2.0%
2	4	8.2%
3	2	4.1%
4	5	10.2%
5	3	6.1%
6	2	4.1%
7	2	4.1%
8	0	0%
9	0	0%
10	3	6.1%
11	4	8.2%
12	5	10.2%
13	9	18.4%
14	9	18.4%
Total	**49**	**100%**

Source: N.C. Department of Transportation.

Structurally deficient bridges are characterized by deteriorated conditions of significant bridge elements that potentially result in reduced load-carrying capacity.[2] Though structurally deficient bridges are not unsafe, they require significant maintenance and repair to remain in service and can act as freight chokepoints due to reduced load limits. Eventually, a major rehabilitation or replacement must occur to address their underlying deficiencies.

A bridge is considered functionally obsolete when it does not meet current design standards, or the volume of traffic carried by the bridge exceeds the level anticipated when the bridge was constructed. Like structurally deficient bridges, functionally obsolete bridges are not unsafe, but their limitations (in terms of traffic volume and load-carrying capacity) restrict the flow of freight. Structurally deficient and functionally obsolete bridges on the North Carolina Freight Network are listed in and shown in Figure 4.30 and Figure 4.31, respectively. Figure 4.32 shows bridges that are both structurally deficient and functionally obsolete.

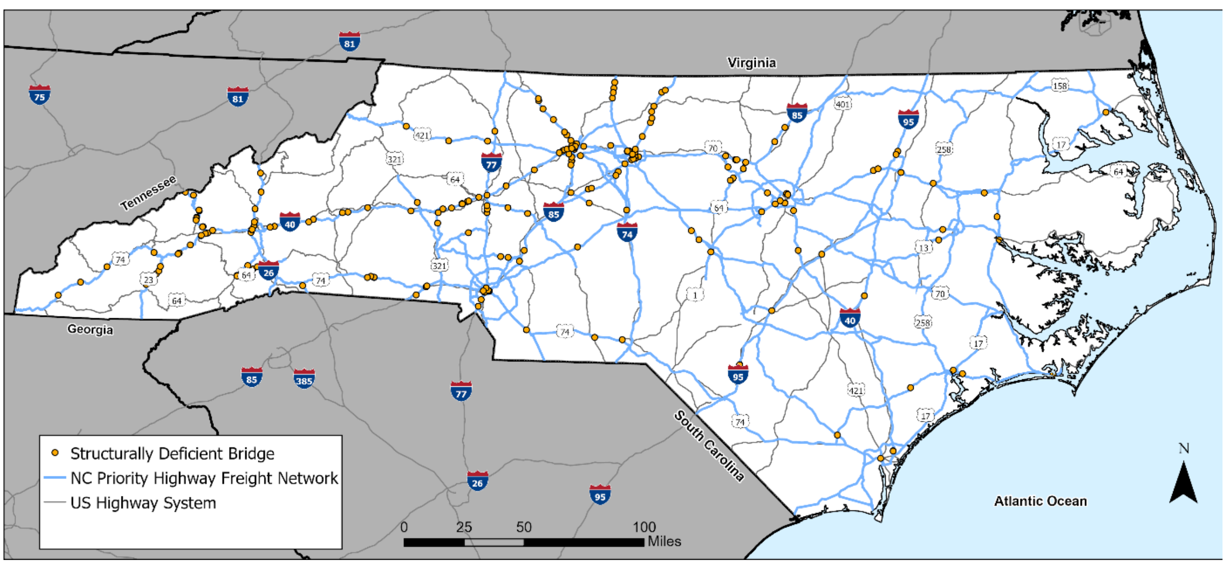
[2] FHWA. Status of the Nation's Highways, Bridges, and Transit Conditions & Performance, 23rd Edition (2020). https://www.fhwa.dot.gov/policy/23cpr/index.cfm

TABLE 4.10 STRUCTURALLY DEFICIENT AND FUNCTIONALLY OBSOLETE BRIDGES, 2022

Highway Division	No. of Structurally Deficient and Functionally Obsolete Bridges	Percent of Total	No. of Structurally Deficient Bridges Only	Percent of Total	No. of Functionally Obsolete Bridges Only	Percent of Total
1	0	0%	1	1.6%	7	0.8%
2	2	1.6%	0	0%	33	3.6%
3	4	3.3%	0	0%	30	3.2%
4	7	5.7%	2	3.20%	77	8.3%
5	7	5.7%	3	4.80%	111	12.0%
6	2	1.6%	0	0%	55	5.9%
7	16	13.0%	15	24.2%	85	9.2%
8	2	1.6%	2	3.2%	51	5.5%
9	16	13.0%	11	17.7%	70	7.6%
10	8	6.5%	6	9.7%	100	10.8%
11	8	6.5%	2	3.2%	37	4.0%
12	19	15.4%	4	6.5%	71	7.7%
13	15	12.2%	3	4.8%	113	12.2%
14	17	13.8%	13	21.0%	85	9.2%
Total	**123**	**100%**	**62**	**100%**	**925**	**100%**

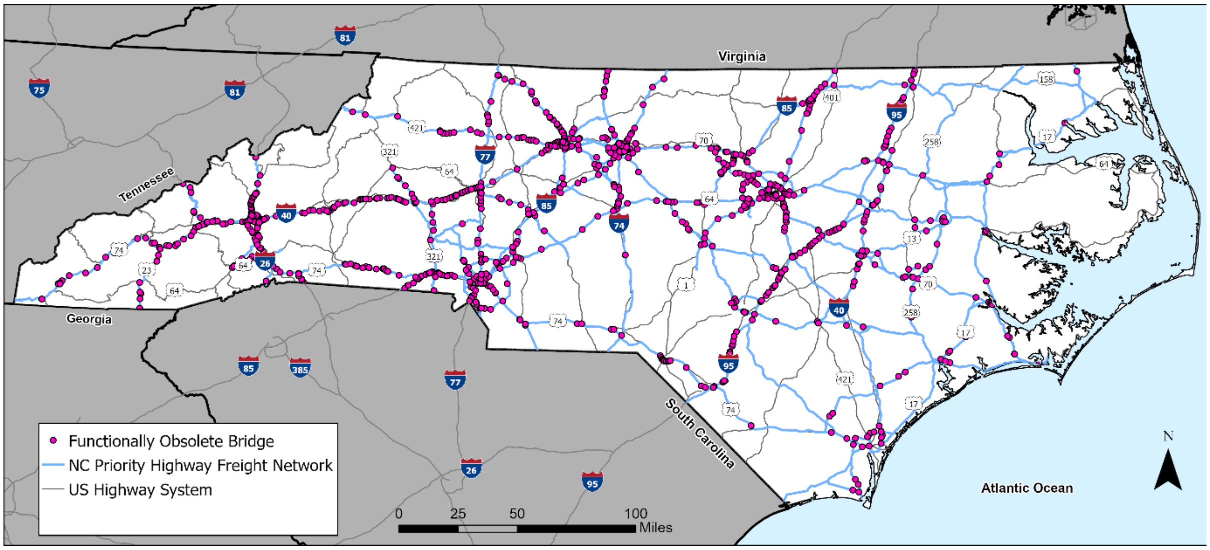
Source: North Carolina. Department of Transportation.

FIGURE 4.30 STRUCTURALLY DEFICIENT BRIDGES, 2022



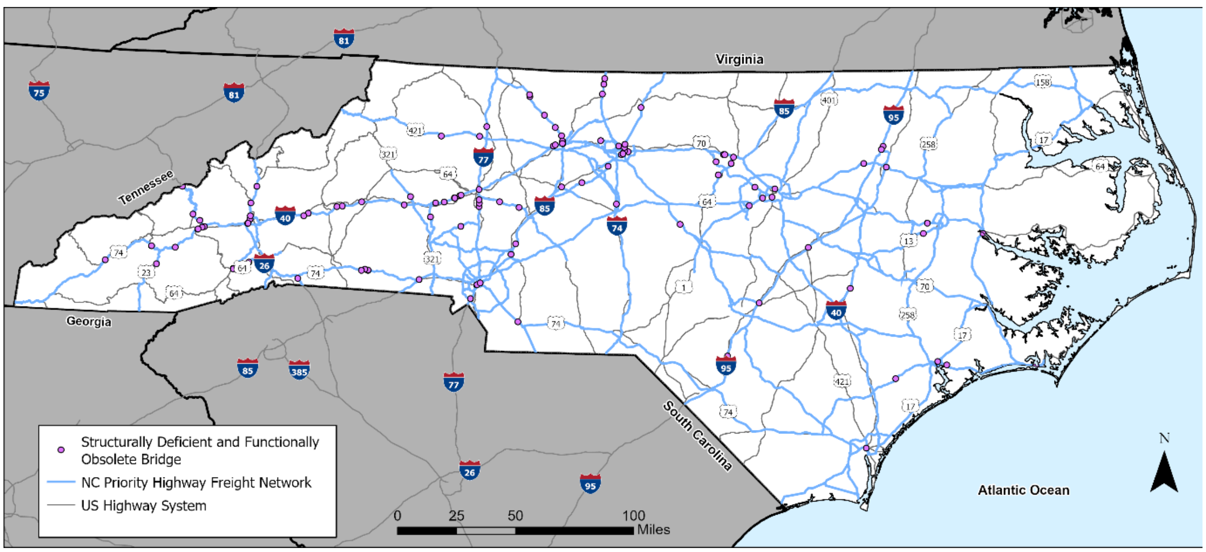
Source: North Carolina Department of Transportation.

FIGURE 4.31 FUNCTIONALLY OBSOLETE BRIDGES, 2022



Source: North Carolina Department of Transportation.

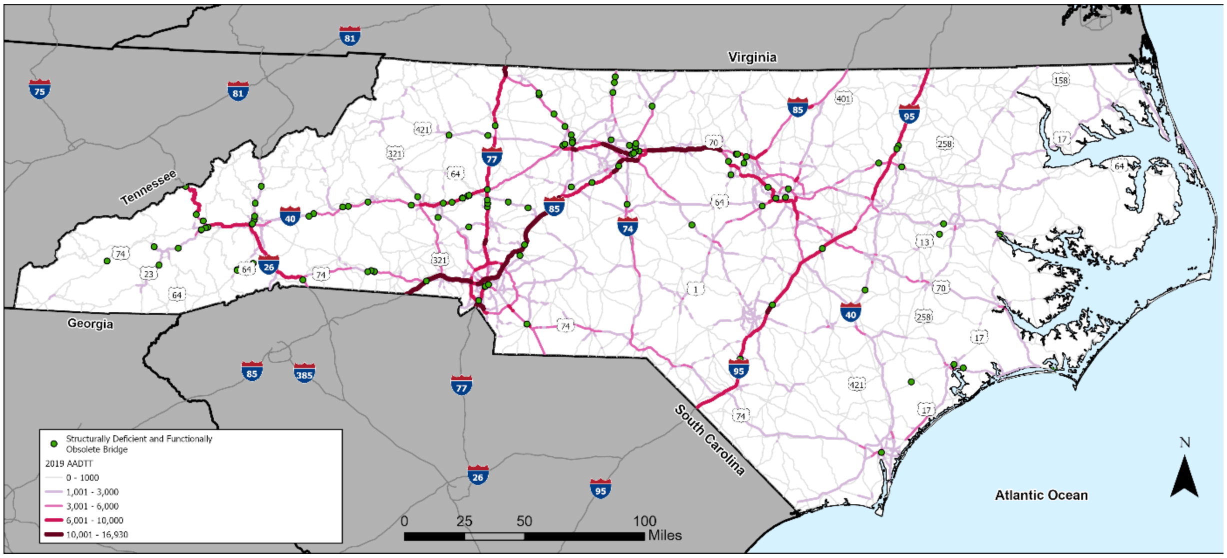
FIGURE 4.32 STRUCTURALLY DEFICIENT AND FUNCTIONALLY OBSOLETE BRIDGES, 2022



Source: North Carolina Department of Transportation.

When the locations of high truck volume routes are viewed in conjunction with the location of structurally deficient and functionally obsolete bridges (Figure 4.33), we begin to see which freight flows are most affected by bridge conditions. Eighteen of these bridges carry interstate routes, which are the backbone of the N.C. priority highway freight system. These include I-26, I-40, I-73, I-74, I-77, I-85, and I-95. Other high truck volume routes with structurally deficient and functionally obsolete bridges include U.S. 52, U.S. 64, and U.S. 74.

FIGURE 4.33 STRUCTURALLY DEFICIENT AND FUNCTIONALLY OBSOLETE BRIDGES WITH TRUCK VOLUME DATA, 2019



Source: North Carolina Department of Transportation.

4.6.2 Pavement

Pavement conditions in North Carolina are rated according to the Pavement Condition Rating (PCR) system.[3] The PCR score displays a composite score determined using a pavement condition survey performed annually for interstate routes and every two years for primary and secondary routes. PCR scores correspond to the following pavement condition assessments:

- Good: PCR greater than or equal to 80;
- Fair: PCR greater than or equal to 60, but less than 80;
- Poor: PCR less than 60.

Table 4.11 summarizes pavement conditions by roadway type. Figure 4.34 depicts pavement conditions on Interstate and U.S. routes while Figure 4.35 shows pavement conditions on N.C. routes. Overall, pavements are in good condition across the state with 65% of secondary route mileage, 58% of N.C. route mileage, 73% of U.S. route mileage and 87% of interstate route mileage achieving a “good” rating. N.C. routes have the highest percentage of route mileage in “Poor” condition with 24%.

[3] North Carolina Department of Transportation. Pavement Condition Survey Manual, 2022. https://connect.ncdot.gov/resources/Asset-Management/AssetManagementDocs/2022%20Asphalt%20Pavement%20Survey%20Manual.pdf

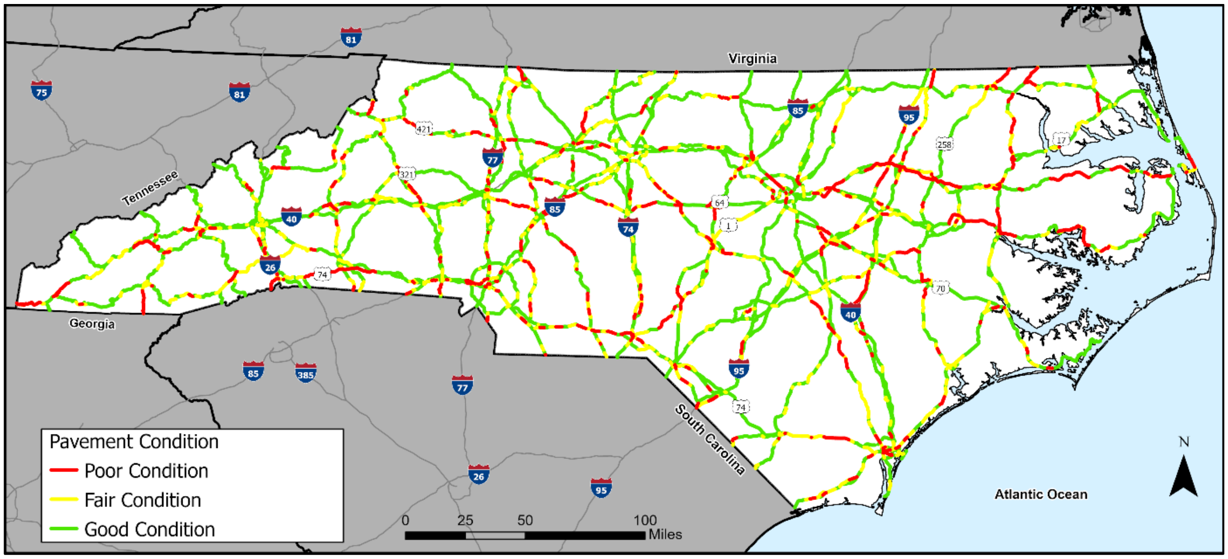
TABLE 4.11 PAVEMENT CONDITIONS BY ROADWAY TYPE, 2020

Condition	Interstate Highways	U.S. Routes	N.C. Routes	Secondary Routes
Poor	13%	24%	8%	3%
Fair	22%	18%	19%	10%
Good	65%	58%	73%	87%
Total	**100%**	**100%**	**100%**	**100%**

Source: North Carolina Department of Transportation; Consultant analysis.

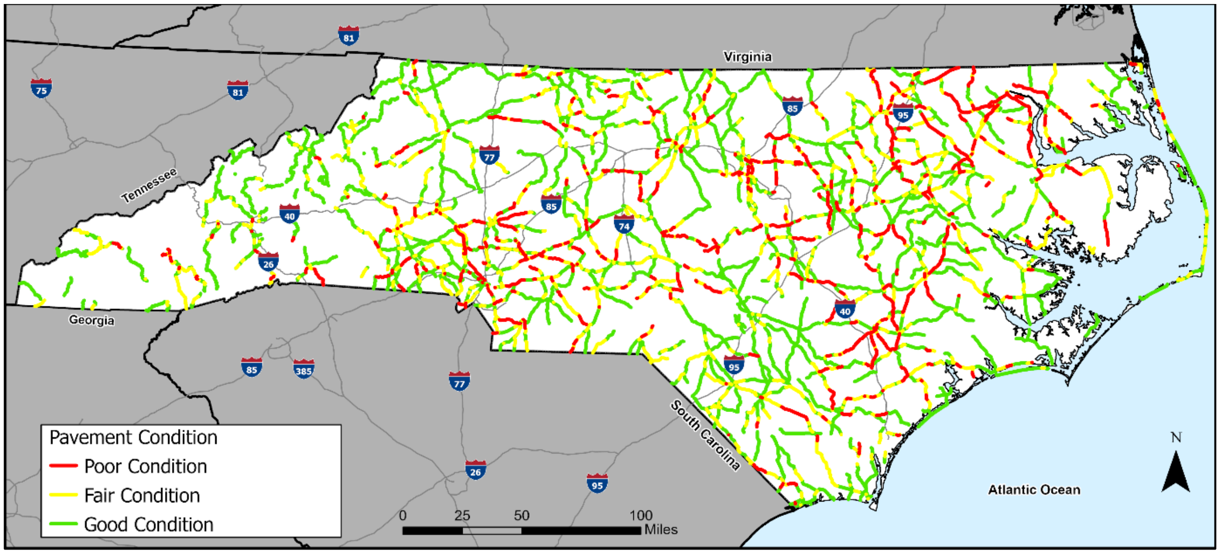
Poor to fair pavement conditions are observed on several high truck volume routes as identified in Section 3.1. For instance, the U.S. 64, U.S. 264 and U.S. 70 corridors, which connect eastern North Carolina to the Triangle Region, all have stretches where PCR values are less than 80. This could directly affect the performance of truck trips to and from the Port of Morehead City and truck trips to the CSX rail intermodal facility at Rocky Mount should conditions worsen. U.S. 74, which links the Port of Wilmington to the Charlotte region, is similar to the other corridors, with many sizable stretches where the PCR values are less than 80.

FIGURE 4.34 PAVEMENT CONDITIONS ON INTERSTATE AND U.S. ROUTES, 2020



Source: North Carolina Department of Transportation; Consultant analysis.

FIGURE 4.35 PAVEMENT CONDITIONS ON NC ROUTES, 2020



Source: North Carolina Department of Transportation; Consultant analysis.

5.0 HIGH VOLUME TRUCK CORRIDORS

This section takes a more in depth look at the highest volume truck corridors in North Carolina. In this analysis, truck volumes, truck travel time reliability, safety and freight intensive land uses are examined simultaneously to determine how they may affect each other and the implications for the core part of the state's freight highway network. The corridors included in this section are I-85, I-40, I-95, I-77, I-26, U.S. 74, U.S. 64, U.S. 264, and U.S. 70.

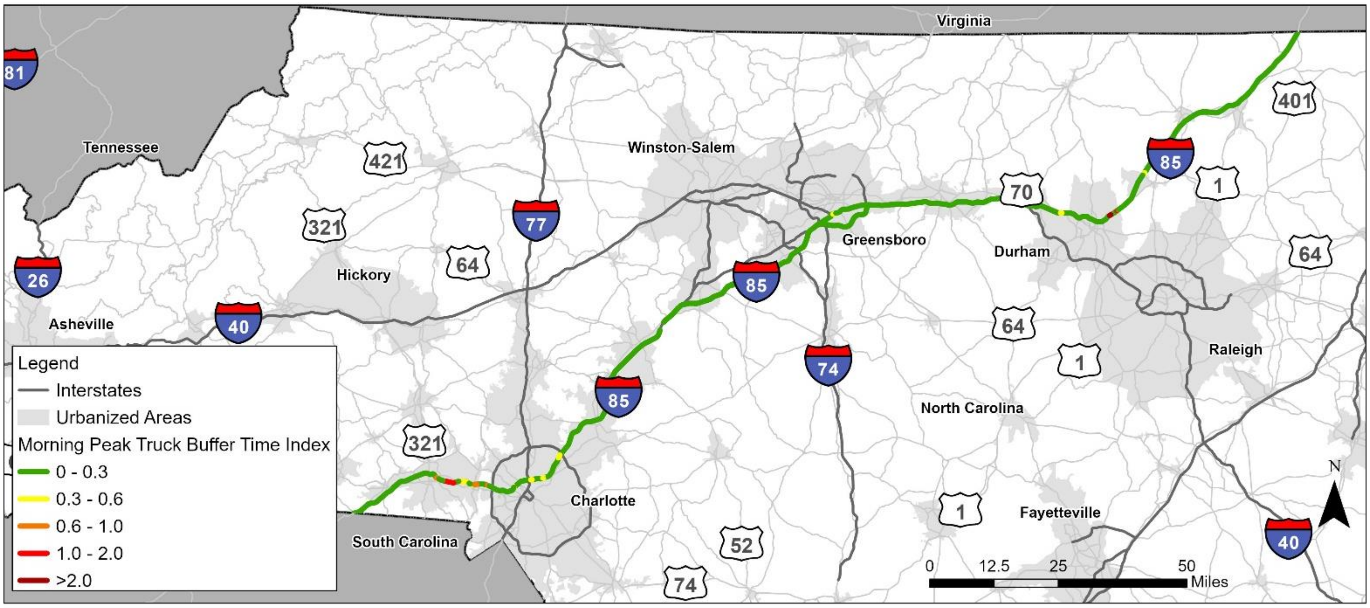
5.1 I-85 Corridor

As noted in Section 3.2, the highest truck volumes in the state occur on I-85 between Greensboro and Durham with over 16,000 trucks per day utilizing this corridor. I-85 is the workhorse of the North Carolina highway freight system as it connects the state’s three largest metropolitan areas: the Charlotte, Triangle, and Triad regions. There are several freight assets along I-85 that are important links in the multimodal freight system, including cargo serving airports (e.g., Charlotte-Douglas International and Raleigh-Durham International airports), CSX, and Norfolk Southern rail intermodal terminals in Charlotte, and various trucking depots located in all three metropolitan areas.

Figures 5.1 and 5.2 display the truck BTI during both the morning and evening peak periods. Truck travel is mainly reliable along the I-85 corridor during both the morning and evening peak periods. For the majority of the corridor, the truck BTI is less than 0.3 (30%). This indicates that motor carriers have little room to factor extra time (i.e., buffer time) into their schedules to ensure on-time arrival for 95% of trips. The majority of the corridor has adequate capacity. Bottlenecks, as indicated by poor reliability, are largely limited to the urban core of the Charlotte region. The evening peak does have poorer reliability overall compared to the morning peak, especially on the corridor between Gastonia and Salisbury.

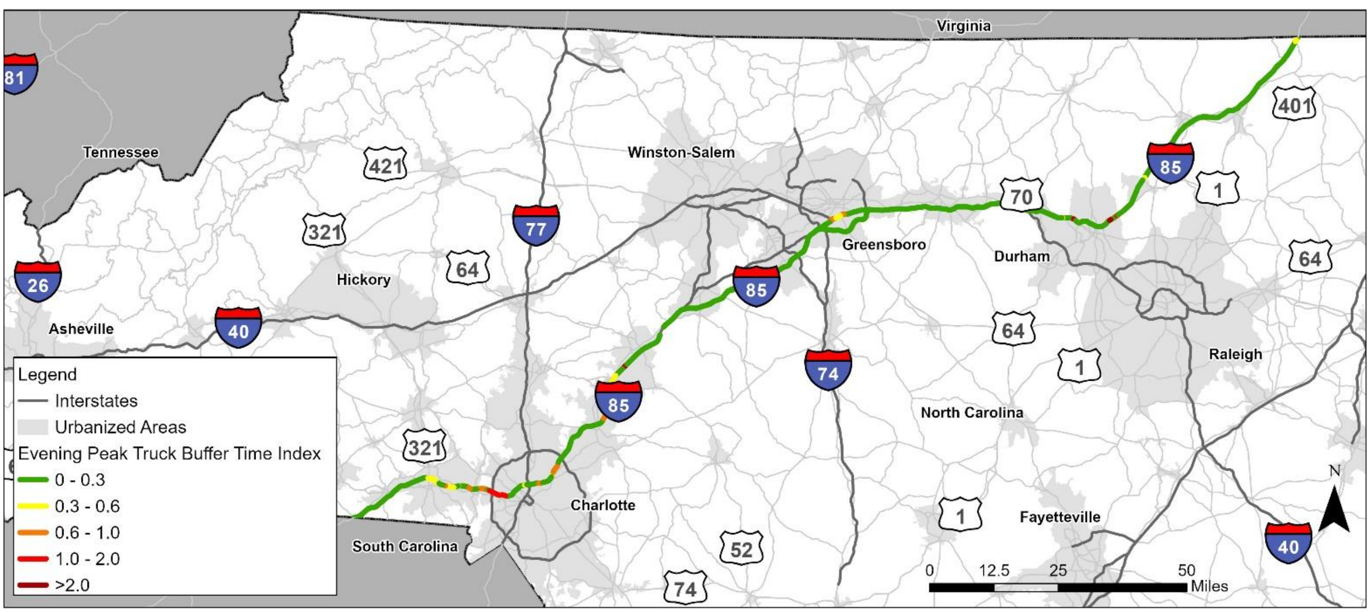
NCDOT currently has planned projects in the STIP to address many of the bottlenecks. NCDOT 2020-2029 STIP project I-5719 (scheduled for construction in 2024) will widen I-85 through the majority of the Gastonia area. NCDOT 2020-2029 STIP project I-3802 (currently under construction) will widen I-85 in the Kannapolis area of the corridor.

FIGURE 5.1 MORNING PEAK: I-85 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

FIGURE 5.2 EVENING PEAK: I-85 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

5.2 I-40 Corridor

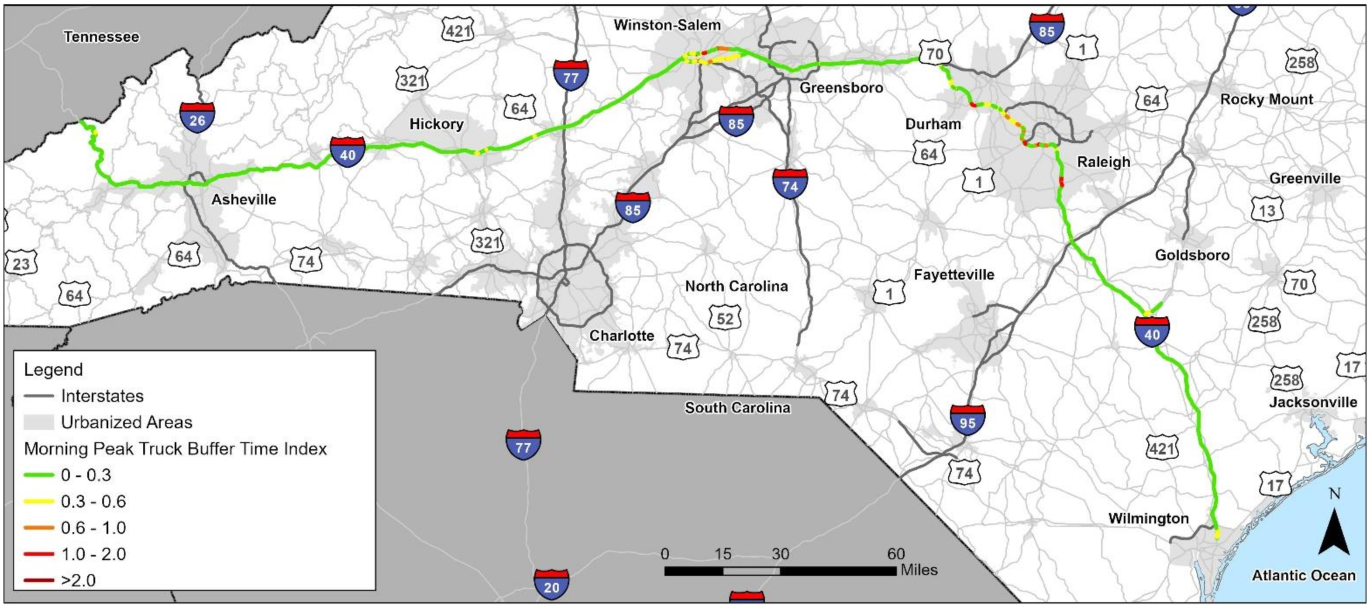
Interstate 40 is one of the most heavily utilized corridors in the state as it is the central corridor through both the Triad and Triangle regions. More than 13,000 trucks travel the I-40 corridor between the two regions on a daily basis. A high number of crashes occur along the I-40 corridor, especially as the interstate approaches Raleigh. The high level of trucking activity and commuter traffic in the Triad and Triangle regions is a likely contributor. There are also several freight assets along this corridor that are important links in the multimodal freight system, including cargo serving airports (e.g. Piedmont-Triad International Airport and Raleigh-Durham International airports) and the Port of Wilmington.

Figures 5.3 and 5.4 display the truck BTI during both the morning and evening peak periods. Truck travel is most reliable along the I-40 corridor between I-77 and its split with I-85 west of Durham. The main exception is in Winston-Salem between I-74 and U.S. 421 on the eastern side of the city. Both the morning and evening peak periods exhibit truck BTIs that are less than 0.3 (30%). This indicates that motor carriers traveling along this portion of the I-40 corridor have to factor in very little extra time (i.e. buffer time) into their schedules to ensure on-time arrival for 95% of trips. However, there are bottlenecks along I-40 as indicated by poor reliability between I-95 and the I-40/I-85 split. This portion of the corridor traverses the urban core of the Triangle region and exhibits truck BTIs as high as 2.0 (200%) during the morning and evening analysis periods.

During the evening analysis period, poor reliability is slightly more dispersed throughout the corridor. Portions of I-40 west of I-26 near Asheville and east of I-77 near Mocksville experience higher BTIs in the evening period. Motor carriers travelling along these links in the highway network may have to factor up to 200% more travel time above their typical budget for traversing these areas.

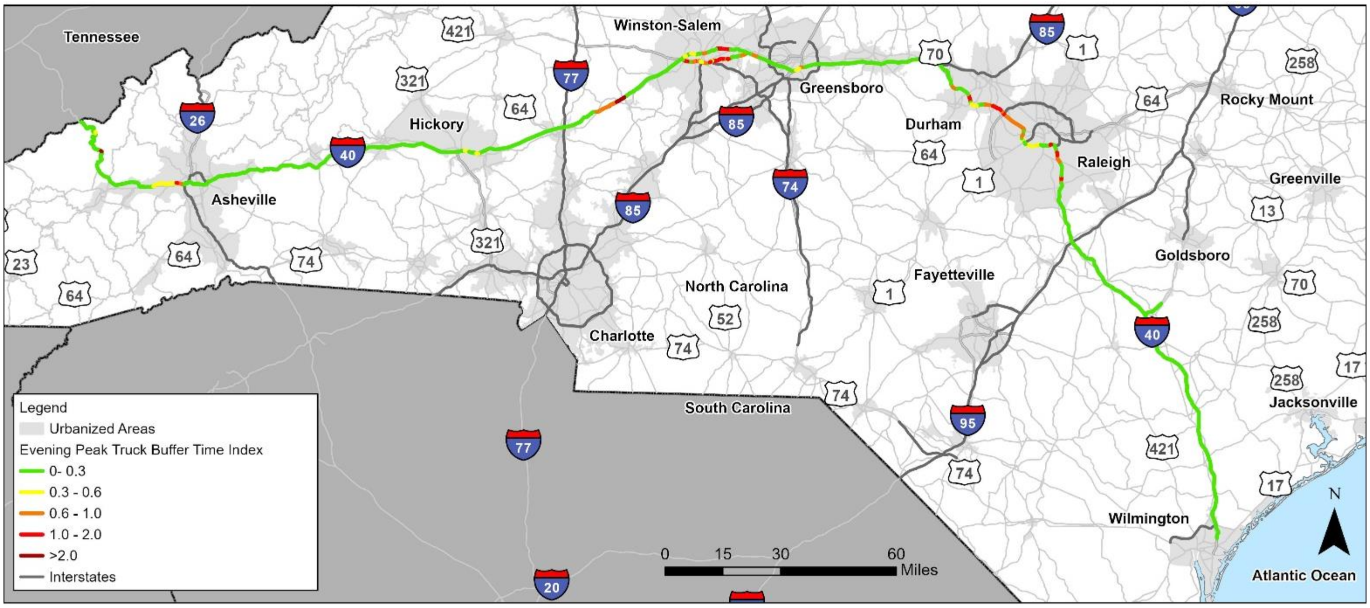
NCDOT currently has planned projects in the STIP to address many of the bottlenecks. NCDOT 2020-2029 STIP projects I-5111 (currently under construction) and I-3306 (scheduled for construction in 2022) will increase capacity in the Triangle region. NCDOT 2020-2029 STIP project I-5981 (scheduled for construction in 2030) will widen I-40 through parts of Winston-Salem. NCDOT 2020-2029 STIP project I-6054 (scheduled for construction post year) plans to widen I-40 west of I-26 in the Asheville region.

FIGURE 5.3 MORNING PEAK: I-40 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: *National Performance Management Research Data Set; Consultant analysis.*

FIGURE 5.4 EVENING PEAK: I-40 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: *National Performance Management Research Data Set; Consultant analysis.*

5.3 I-95 Corridor

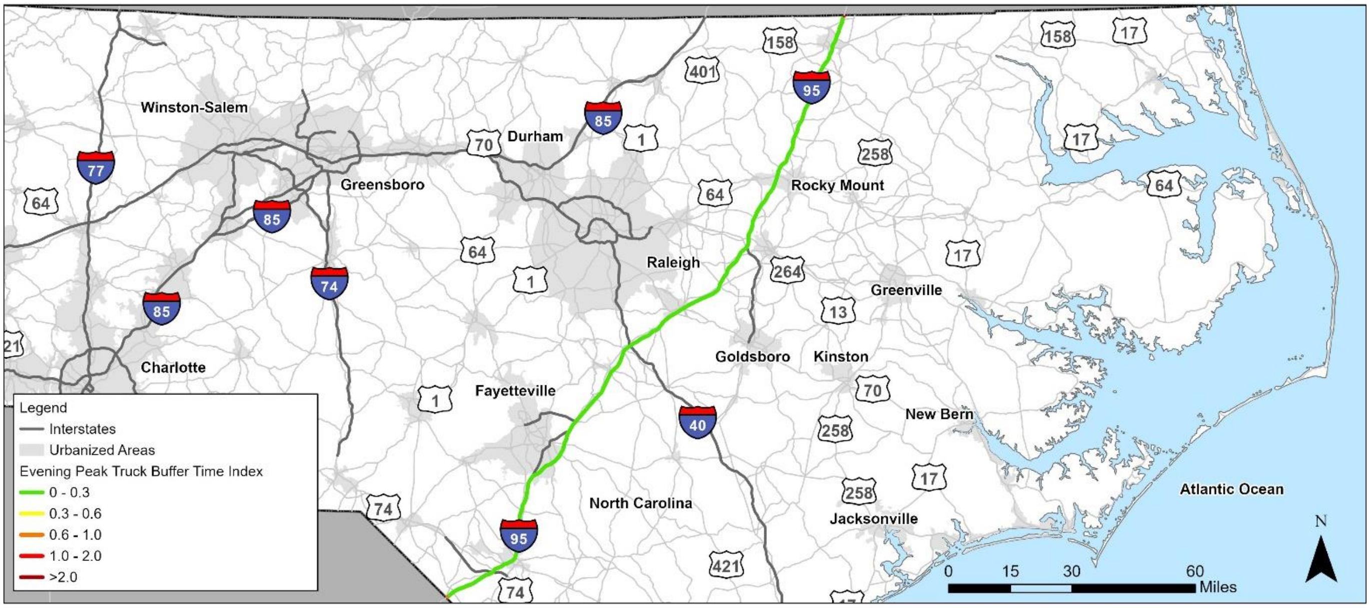
Interstate 95 is an essential north-south shipping corridor for the East Coast of the United States, connecting major population centers such as Miami, Washington, D.C., New York, and Boston. Within North Carolina, I-95 has more modest truck volumes when compared to I-85 and I-40. The highest AADTT values on I-95 are in the 7,000 – 8,000 range; however, the recently opened CSX rail intermodal terminal in Rocky Mount is located directly along the I-95 corridor, which increases the potential for both truck and commuter traffic growth in this area.

Figures 5.5 and 5.6 display the truck BTI during both the morning and evening peak periods. Truck travel is mostly reliable along the entirety of the I-95 corridor. Both the morning and evening peak periods exhibit truck BTI that are primarily less than 0.3 (30%). Truck travel time performance on I-95 is aided by the lack of major metropolitan areas along its length. Only the Fayetteville metropolitan area is directly located along the corridor, which is relatively small when compared to other population centers in North Carolina. Thus, motor carriers operating on I-95 do not have to compete for capacity with commuter vehicles to the same extent as other major freight corridors throughout the state. NCDOT 2020-2029 STIP projects I-5986 (currently under construction) and I-5987 (scheduled for construction in 2023) will increase capacity along I-95 from the South Carolina state line to Fayetteville. STIP project I-5986 will also install broadband fiber along I-95 throughout North Carolina.

FIGURE 5.5 MORNING PEAK: I-95 TRUCK TRAVEL TIME RELIABILITY, 2019

Source: National Performance Management Research Data Set; Consultant analysis.

FIGURE 5.6 EVENING PEAK: I-95 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

5.4 I-77 Corridor

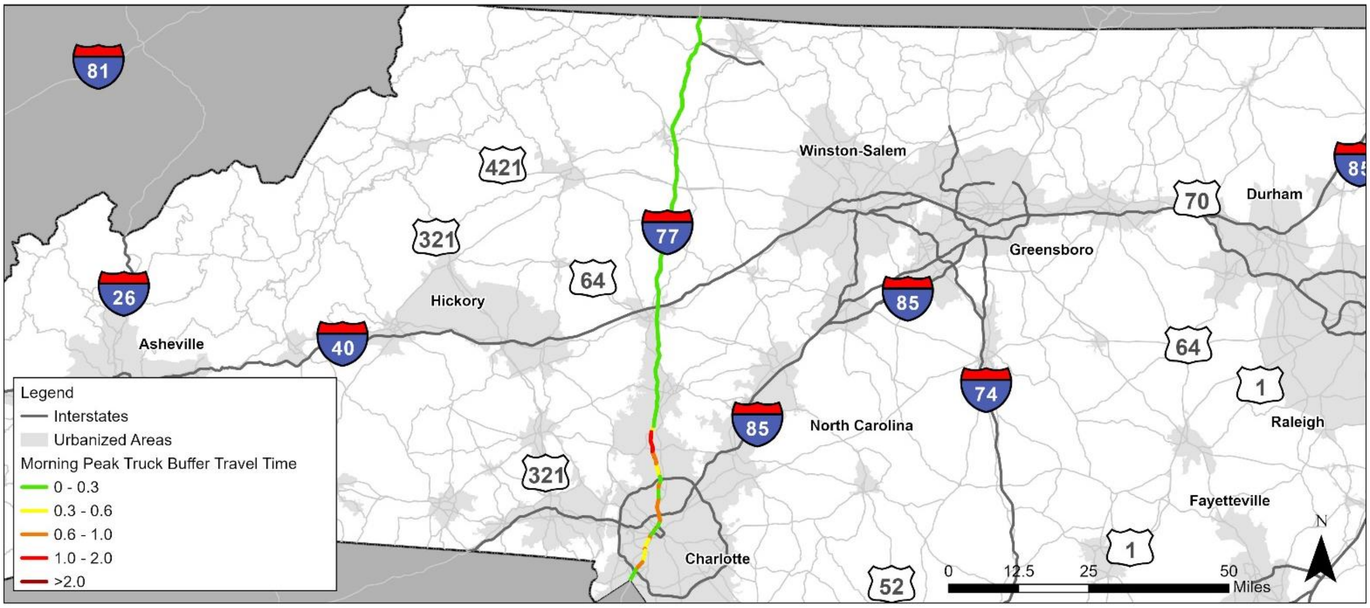
Interstate 77 is a key north-south shipping corridor for North Carolina as it connects the Charlotte region to major Midwestern markets, namely Columbus, Cleveland and Pittsburgh. In addition, it provides primary access to the Port of Charleston for shippers in the Charlotte metropolitan area, giving them an alternative to the Port of Wilmington, as both ports are about 200 miles from Charlotte.

I-77 experiences significant truck volumes relative to other major interstate highways within North Carolina. Daily truck volumes climb as high as 11,000 trucks per day as I-77 passes west of downtown Charlotte. Volumes approach 10,000 trucks per day near the North Carolina-Virginia state line.

Figures 5.7 and 5.8 display the truck BTI during both the morning and evening peak periods. Poor truck travel time reliability on I-77 is limited to the Charlotte metropolitan area. Both the morning and evening peak periods exhibit truck BTIs as high as 2 (200%) along I-77 from the city of Charlotte to the Mecklenburg-Iredell County line. North of the Charlotte region, truck travel is very reliable as there are no other major population centers utilizing the highway for commuter travel.

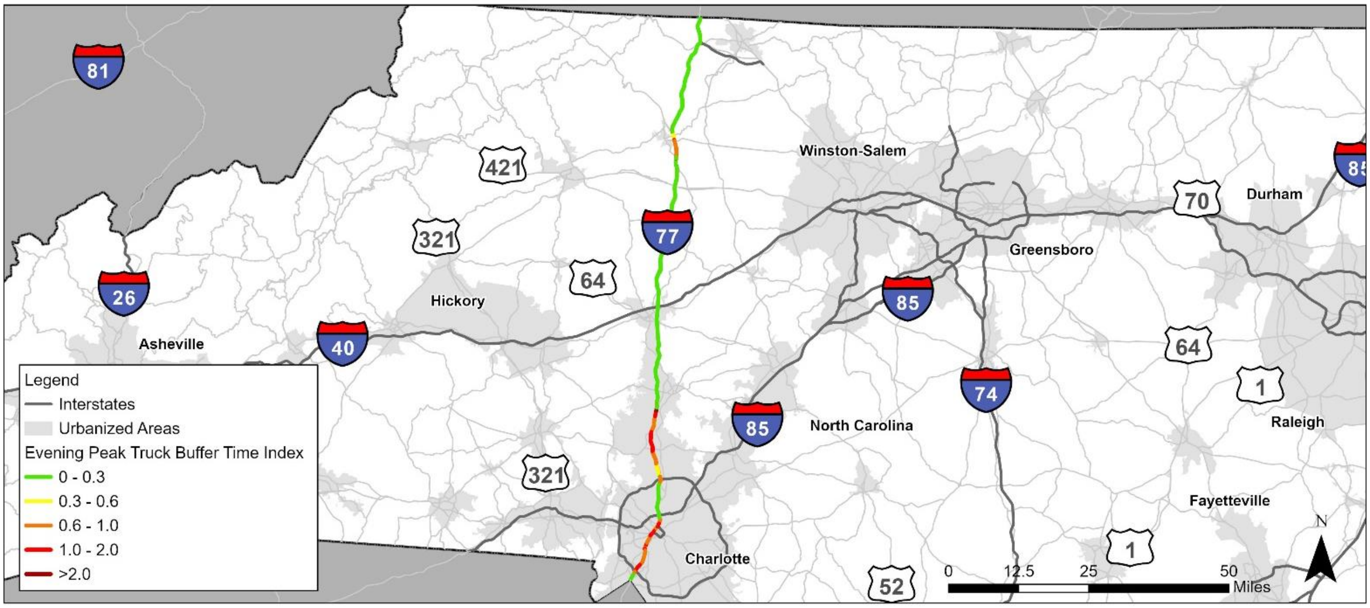
NCDOT does not have any STIP projects in the Charlotte region that will directly benefit trucks. NCDOT 2020-2029 STIP projects I-5718 (scheduled for construction post year) and I-5405 (currently under construction) will construct managed lanes that trucks will be restricted from accessing. The shift of some automobiles to the managed lanes will likely free up some general-purpose lane capacity that will indirectly benefit trucks traveling through the area.

FIGURE 5.7 MORNING PEAK: I-77 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

FIGURE 5.8 EVENING PEAK: I-77 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

5.5 I-26 Corridor

Interstate 26 has modest truck volumes when compared to daily truck volumes of other major interstate highways in the state (namely I-77, I-85 and I-40). The portion of I-26 south of Asheville (between U.S. 25 and I-40) has the largest daily truck volumes along the corridor. At this location, volumes reach as high as 9,000 trucks per day. Volumes north of Asheville decline significantly, suggesting that Asheville is the major terminus (either origin or destination) of truck trips along I-26.

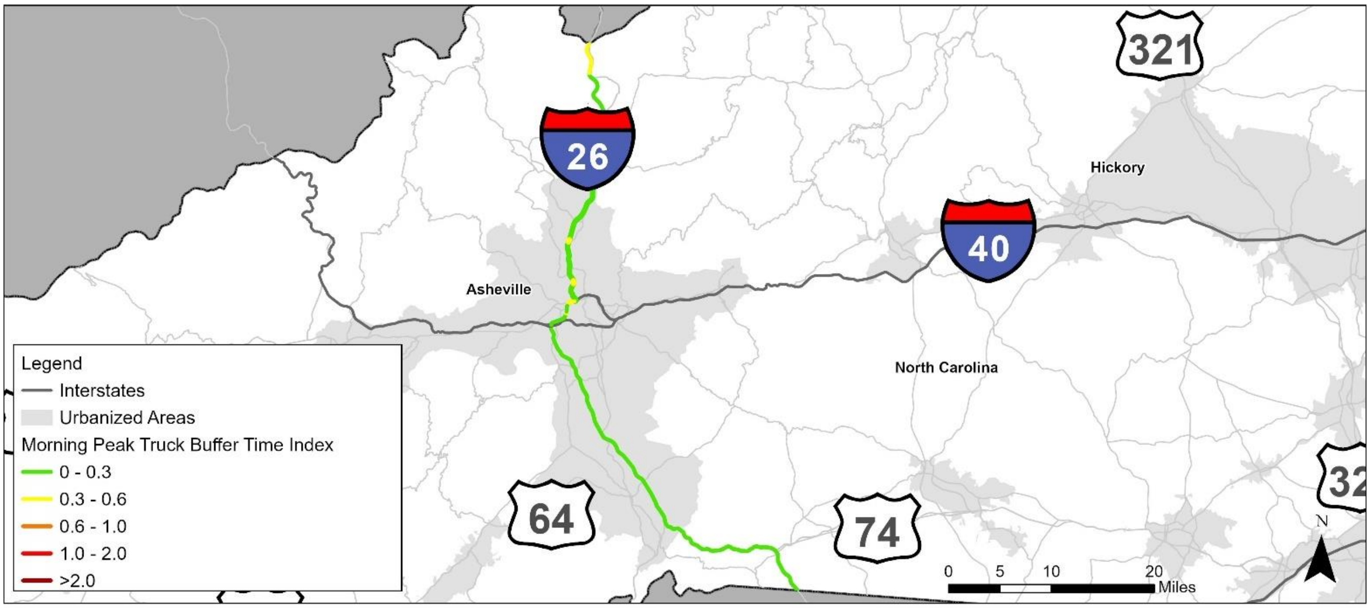
Overlaying travel time reliability data with the location of freight intensive business establishments provides insight on how well the infrastructure is meeting industry service needs. Figure 5.9 and Figure 5.10 display the truck BTI for the morning and evening peak periods. Truck travel is very reliable along I-26 in the morning peak period with truck BTIs below 0.3 (30%) with the exception of small portions of I-26 within Asheville that exhibit unreliable travel. This occurs at the I-26/I-40 interchange and where I-26 merges with I--240. Additionally, I-26 near the North Carolina-Tennessee state line exhibits poorer truck travel time reliability; however, trucks navigating mountainous terrain is a likely factor.

The evening peak period is less reliable for truck travel time along the I-26 corridor. Numerous portions of the facility from U.S. 25 near Hendersonville northward to U.S. 19 in Weaverville have high truck BTIs with some exceeding 1.0 (100%).

Relative to other freight corridors throughout the state, there are fewer freight-intensive industries (i.e. manufacturing and distribution) along the I-26 corridor as captured by the Data Axle business location data. This is partially a reflection of the influences of healthcare, hospitality, and local government on the Asheville regional economy as evidenced by its largest employers. However, there are several freight-intensive industries located along the French Broad River. North of I-240, I-26 runs parallel to the French Broad River and many of the industries located in this area Asheville are likely frequent users of I-26. There is also a freight cluster south of Lake Julian between U.S. 25 and I-26. In addition, there is a cluster of freight-intensive land uses bounded by I-26, I-40 and N.C. 191 to the southwest of downtown Asheville. This freight cluster also likely utilizes I--26.

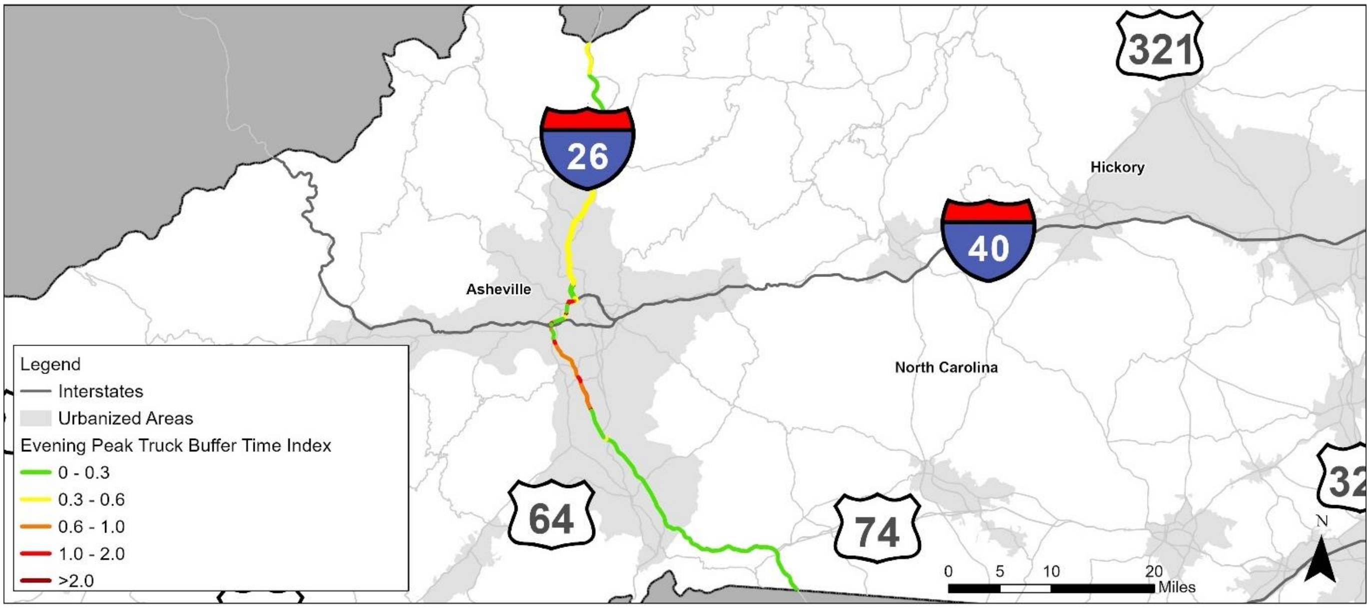
NCDOT has numerous STIP projects planned to improve the corridor. NCDOT 2020-2029 STIP projects I-4400 and I-4700 (both currently under construction) will widen I-26 from Hendersonville to I-40. NCDOT 2020-2029 STIP project I-2513 (scheduled for construction in 2024) will widen I-26/I-240 and redesign the current I-26 and I-240 interchange. STIP Project A-0010AA (scheduled for construction in 2030) will also widen I-26 from the northern terminus of I-2513 northward to Weaverville.

FIGURE 5.9 MORNING PEAK: I-26 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

FIGURE 5.10 EVENING PEAK: I-26 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

5.6 U.S. 74 Corridor

U.S. 74 is an important route for motor carriers travelling between the Port of Wilmington and I-95 south, or the Charlotte region. At its busiest locations, U.S. 74 carries nearly 6,000 trucks per day. The Monroe Expressway, a toll road along the corridor that bypasses Monroe, NC, was opened in late 2018. NCDOT does not have truck percentages collected for the road available at the time of this plan, but the North Carolina Turnpike Authority estimates 1,000 – 2,000 trucks use the facility daily.

Figure 5.11 and Figure 5.12 display the truck BTI. Reliability performance along U.S. 74 is superior along those portions that are limited access. The Business and Alternate routes notwithstanding (near I--95 and I-74), U.S. 74 provides reliable truck travel from Wilmington to the eastern suburbs of Charlotte. U.S. 74 converts to a grade-level highway west of the Great Pee Dee River near Rockingham. Truck travel time reliability begins to decline as U.S. 74 approaches Charlotte . Truck travel time reliability along U.S. 74 is poorest within the I-485 loop around Charlotte and westward through Gastonia until it reaches I-85. Truck travel time reliability improves to the top category from I-85 westward to I-26.

While fewer manufacturing and distribution facilities are located directly along U.S. 74, the corridor is anchored by the Port of Wilmington in the east and the Charlotte region's freight assets in the west. It is likely that a considerable number of shippers and carriers are affected by travel time reliability on U.S. 74. This is especially true of shippers and carriers in the Charlotte area who rely on the port.

Similar to the I-77 corridor in Charlotte, NCDOT does not have any STIP projects in the region that will directly benefit trucks. NCDOT 2020-2029 STIP projects U-2509 (scheduled for construction in 2023) and U-6103 (scheduled for construction in 2031) will construct managed lanes that trucks will be restricted from accessing. The shift of some automobiles to the managed lanes will likely free up some general-purpose lane capacity that will indirectly benefit trucks traveling through the area.

FIGURE 5.11 MORNING PEAK: U.S. 74 TRUCK TRAVEL TIME RELIABILITY, 2019

Source: National Performance Management Research Data Set; Consultant analysis.

FIGURE 5.12 EVENING PEAK: U.S. 74 TRUCK TRAVEL TIME RELIABILITY, 2019

Source: National Performance Management Research Data Set; Consultant analysis.

5.7 U.S. 64, U.S. 264, and U.S. 70

U.S. 64, U.S. 264 and U.S. 70 are important links between the communities in eastern North Carolina and the Triangle. Section 6.3 discusses the future plans to upgrade parts of these U.S. highways to Interstate highways. In addition, U.S. 70 provides primary access to the Port of Morehead City. As mentioned in Section 3.1, U.S. 70 carries nearly 3,000 trucks per day.

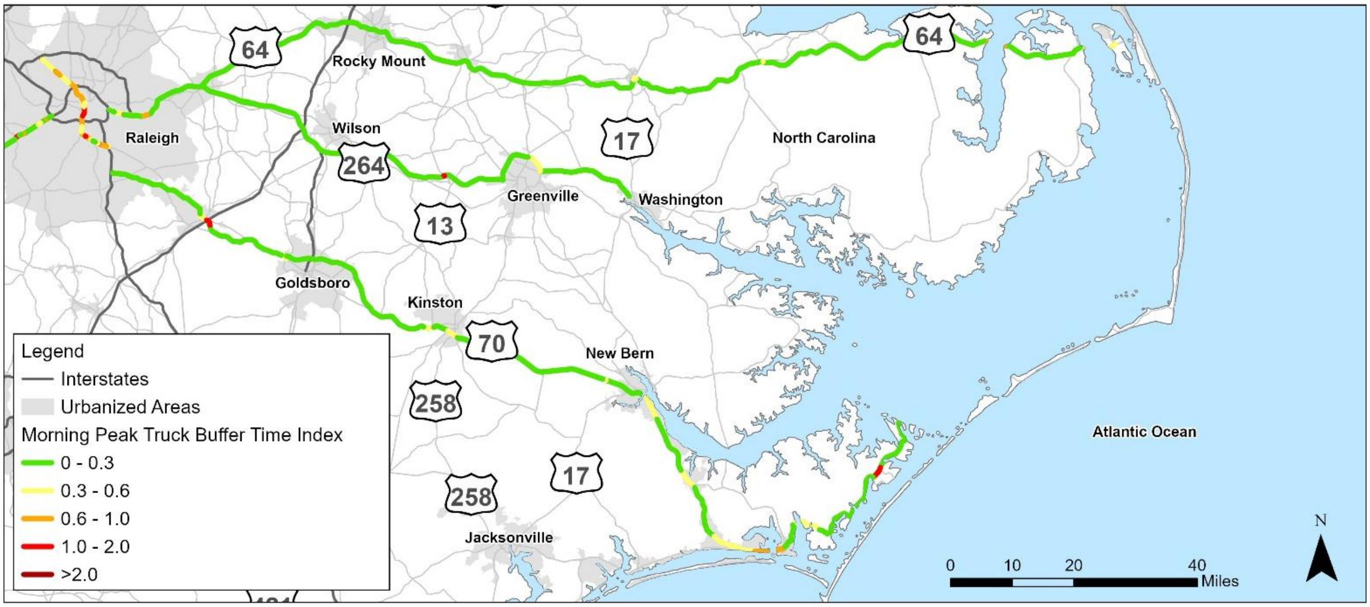
Figure 5.13 and Figure 5.14 display the truck BTI for the morning and evening peak periods,. Significant portions of U.S. 64, U.S. 264, and U.S. 70 provide limited access service to motor carriers. Generally, those portions provide reliable truck travel times as indicated by their truck BTIs which tend to be below 0.3 (30%). This implies that motor carriers have very little buffer time to factor into their schedules for on-time performance when traversing these links.

There are fewer businesses in freight-intensive industries located along U.S. 64, U.S. 264, and U.S. 70 than elsewhere on the state system; however, the Port of Morehead City is directly served by U.S. 70. Likewise, the CSX intermodal rail terminal at Rocky Mount is directly served by U.S. 64 and provides primary access to shippers and carriers in the Triangle to the new facility.

U.S. 70 is perhaps the most challenged of the three routes based on truck travel time reliability. Significant portions of U.S. 70 exhibit reliability measures that exceed 0.6 (60%), mainly from Havelock to the Port of Morehead City. This poses a challenge for motor carriers who must access the Port of Morehead City and limits the ability of U.S. 70 to serve as a direct route between the Triangle and the Port of Morehead City. Alternatively, trucks may utilize I-40 and N.C. 24, which are slightly longer routes.

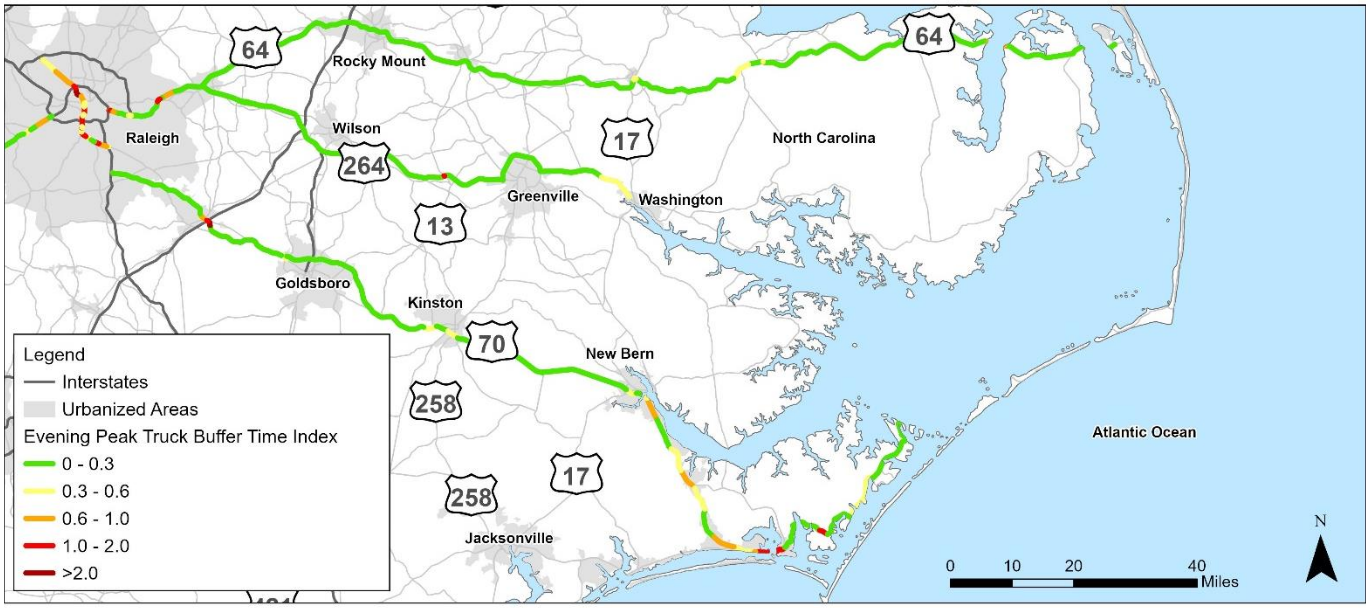
NCDOT does have plans in the STIP to improve U.S. 70. NCDOT 2020-2029 STIP project R-1015 (currently under construction) will provide a bypass around Havelock. NCDOT 2020-2029 STIP project R-5777 (currently under construction) will install broadband fiber from I-40 to the Port of Morehead City. This will allow the installation of various Intelligent Transportation System projects.

FIGURE 5.13 MORNING PEAK: U.S. HIGHWAYS 64, 264, AND 70 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

FIGURE 5.14 EVENING PEAK: U.S. HIGHWAYS 64, 264, AND 70 TRUCK TRAVEL TIME RELIABILITY, 2019



Source: National Performance Management Research Data Set; Consultant analysis.

5.8 Summary

This section examined the state's highest truck volume corridors. These corridors form the basis of North Carolina's priority freight highway system. This information will be used to inform the process of identifying the state's priority freight highway network, which will consist of the PHFN, CUFC, CRFC and other facilities deemed important to the movement of statewide freight. Examining the data on land use and business establishments relative to truck volumes on the highway facilities reveals that while many freight-intensive businesses have located on the interstates and major highways, there are still numerous other roadways that serve large numbers of these businesses. These other freight corridors will be identified and analyzed in the freight system designation process.

6.0 FUTURE PERFORMANCE AND LONG-TERM TRENDS

6.1 Commodity Flows

According to commodity flow data released as part of version 5 of the Freight Analysis Framework (FAF5) and consultant analysis to estimate through traffic, over 991 million tons of cargo are expected to be transported over North Carolina's highways in 2050 (Table 6.1). This represents an increase of nearly 42% over 2017 flows. A large portion of truck flows, about 35%, are expected to continue to be internal to North Carolina and internal truck tonnage is expected to have high growth (51%) over the next 33 years.

Largely, the same top commodities by weight transported by highway in 2017 are expected to remain the top commodities in 2050. This projection results primarily from the use of alternative modes of transportation, such as new pipelines to move larger volumes of gasoline in the future. In addition, the demand for gasoline is projected to decline over time with the adoption of alternative fuels and vehicle electrification.

Such a significant increase in total tonnage, especially in bulk commodity groups, is likely to have significant consequences for the North Carolina highway system. As only 37%of highway commodity flows are expected to be through movements, the implication is that many of the truck trips associated with the highway commodity flows will travel on non-interstate roadways for some portion of the trip. In the absence of a modal shift, motor carriers will be forced to accommodate demand with heavier and more frequent trucks. This will contribute to congestion in the state's urban areas as heavy trucks compete with commuters for highway capacity. It will also further strain pavements and bridges.

TABLE 6.1 HIGHWAY COMMODITY FLOWS BY DIRECTION, 2050

Direction	2050 Tonnage	Percent of Total	Growth Percentage from 2017
Inbound	140,591,900	14%	79%
Outbound	141,411,900	14%	89%
Internal	354,692,000	35%	51%
Through	374,820,070	37%	74%
Total	1,011,515,870	100%	42%

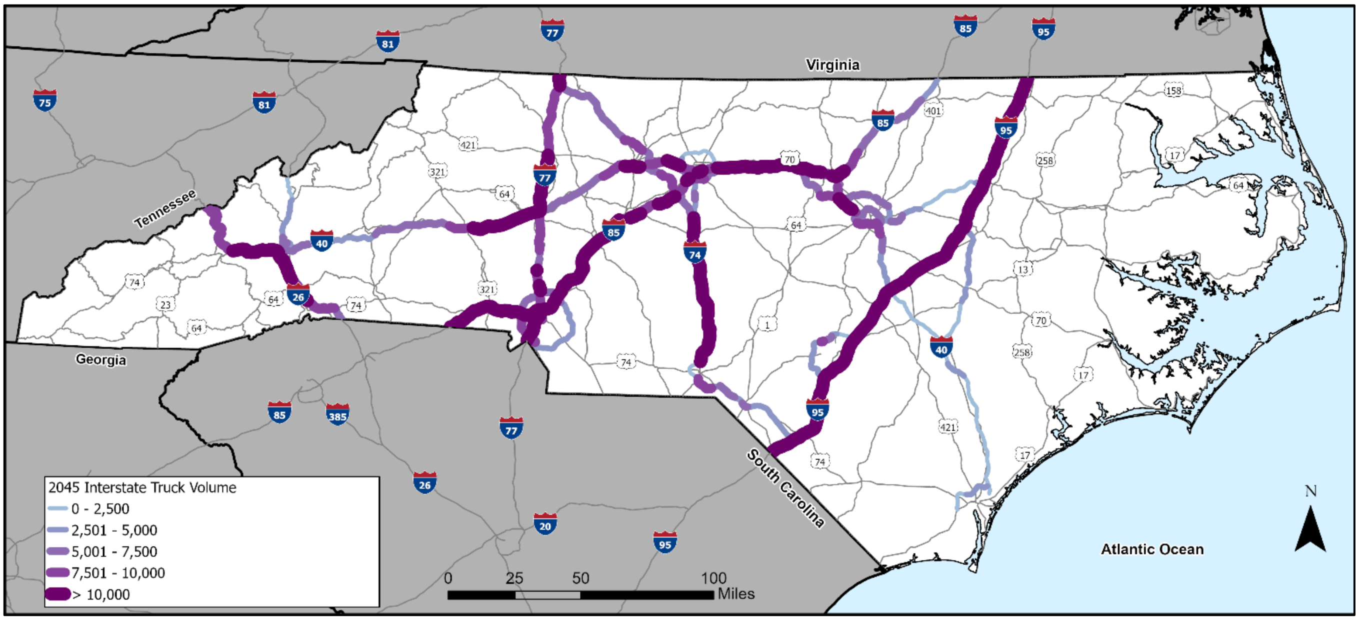
Source: Disaggregate Freight Analysis Framework version 5; Consultant analysis.

6.2 Highway System Usage and Performance

As shown in Figure 6.1, which shows the 2045 truck volumes as predicted by the statewide travel demand model, the interstate highway system is expected to continue to carry the heaviest truck flows across North Carolina as also indicated by the 2017 daily truck volume data (see Figure 3.1). Much of the interstate highway system is predicted to experience truck volumes that exceed 7,500 trucks per day.

Figure 6.1 also indicates that in 2045, the highest truck volumes in the state are estimated to occur on I-85 between Greensboro and Durham. I-85 is currently the heaviest utilized freight corridor in North Carolina based on truck volumes and is expected to maintain that role through 2045. Future year truck volumes on I-85 range from 10,000 to 16,000 trucks per day. Consistent with the 2017 truck volume data, other interstate highways predicted to have high truck volumes include I-77, I-40, I-26 and I-95. Portions of I-77 nearest to Charlotte are predicted to carry more than 10,000 trucks per day, which represents an increase over its 2017 values.

FIGURE 6.1 2045 DAILY TRUCK VOLUMES ON INTERSTATE HIGHWAYS

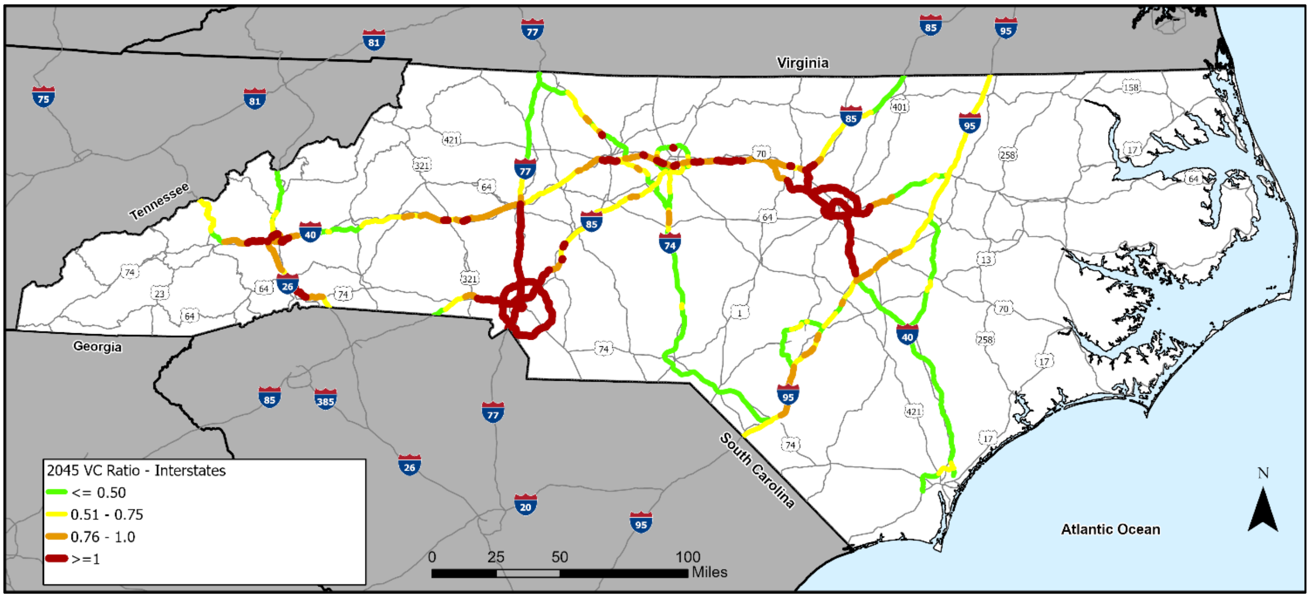


Source: NCDOT Travel Demand Model; Consultant analysis.

Volume-to-Capacity (V/C) ratios on the interstate highway system are shown in Figure 6.2 for the forecast year 2045. V/C ratios are calculated by dividing the total volume of traffic on a roadway by its capacity, indicating the severity of congestion on a given roadway. The results of the statewide travel demand model indicate that much of the state's interstate highway system is expected to approach capacity-constrained conditions, as indicated by V/C ratios exceeding 0.75, by 2045. This is most pronounced on the I-85 corridor between the Charlotte and Triangle regions, the I-77 corridor from I-40 to the Charlotte region, the I-40 corridor from I-95 to the Asheville region, and I-26 from the Asheville region to the South Carolina state line. These are also the most heavily utilized freight corridors in the state. The I-95 corridor displays slightly better V/C ratios than the other capacity-constrained interstate highways, and is an important corridor for North Carolina shippers who must access businesses and customers along the eastern seaboard.

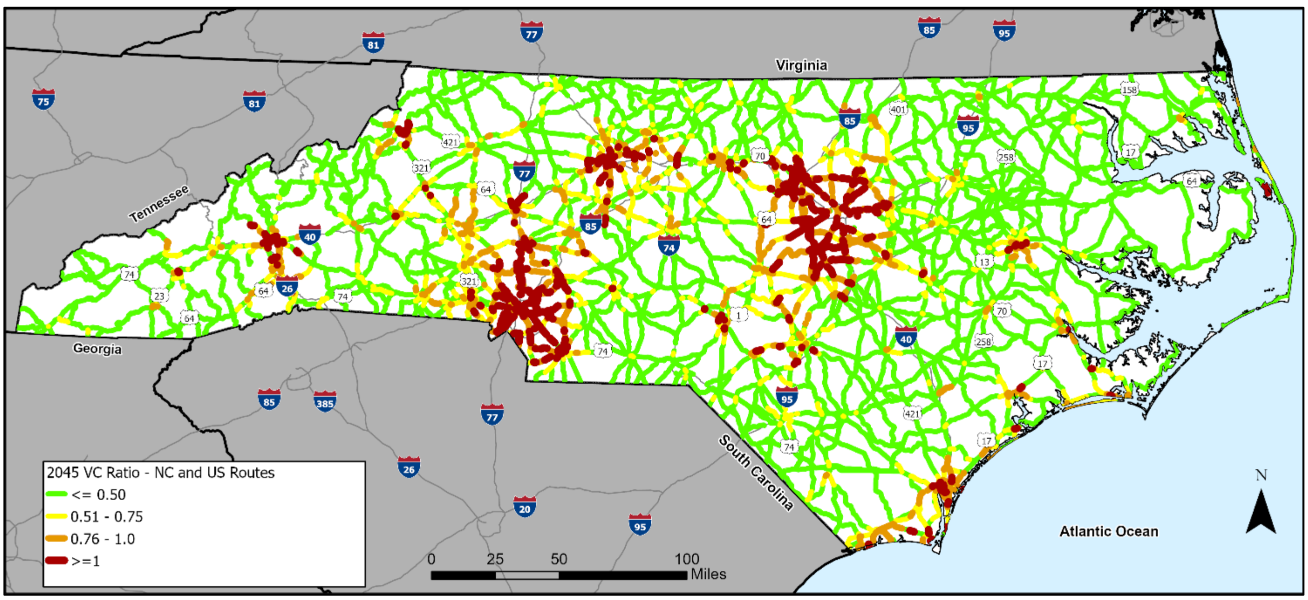
The result for non-interstate highways, shown in Figure 6.3, suggests that much of the predicted congestion will be limited to the Charlotte, Triad, Triangle, Wilmington, and Asheville regions. Congestion on non-interstate highways in the Charlotte, Triad, and Triangle regions is predicted to be widely dispersed throughout. Wilmington congestion is mainly confined to New Hanover County, which includes the Port of Wilmington. Asheville congestion is primarily on roadways providing parallel routes to I-26, such as U.S. 25.

FIGURE 6.2 2045 VOLUME-TO-CAPACITY RATIOS ON INTERSTATE HIGHWAYS



Source: NCDOT Travel Demand Model; Consultant analysis.

FIGURE 6.3 2045 VOLUME-TO-CAPACITY RATIOS ON U.S. AND N.C. ROUTES



Source: NCDOT Travel Demand Model; Consultant analysis.

6.3 Future Interstate Highways

Numerous interstate highways are due to open in North Carolina over the next several years.[4] These include the I-87 Raleigh-Norfolk Corridor, U.S. 117/I-795, U.S. 70 (future I-42), and the I-73/I-74 North-South Corridor. I-885

[4] Federal Highway Administration Office of Planning, Environment, and Realty. http://www.fhwa.dot.gov/planning/national_highway_system/high_priority_corridors/hpcfitext.cfm

was just recently opened to provide an improved connection between I-85 and I-40 in Durham, NC. The opening of these routes will help to alleviate many of the performance challenges identified in Sections 4.2 and 4.3 and discussed in greater detail in Section 5.2.

As its name suggests, the Raleigh-Norfolk Corridor will connect the Triangle in North Carolina to the Hampton Roads region of Virginia. Currently, there is no direct route between these two metropolitan areas. I-87 will follow a route that includes the cities of Raleigh, Rocky Mount, Elizabeth City, and Norfolk, VA. It will utilize the existing rights-of-way from U.S. 264, U.S. 64, and U.S. 17. The new highway will allow shippers in the Triangle and Northeast Region of NC increased access to the Port of Norfolk.

I-795 will be extended along the existing U.S. 117 right-of-way to connect with I-40 near Faison in Duplin County. Extending I-795 to I-40 will decrease the distance (and corresponding average travel time) between the Port of Wilmington and Rocky Mount. This will be especially useful for shippers and carriers transporting containers between the CSX rail intermodal terminal at Rocky Mount and the Port of Wilmington. Given the CSXT and NCDOT rail lines that exist between these two locations, I-795 can serve as an alternative modal route increasing the redundancy and resiliency of the multimodal freight system.

Accessibility to the Port of Morehead City from the Triangle will improve with the opening of I-42. The future interstate will utilize the existing U.S. 70 right-of-way to connect the Port of Morehead City to the Triangle near Garner. The analysis in Section 5.7 identified the U.S. 70 corridor as one of the most challenged primary freight routes based on truck travel time reliability. Converting this route to a limited-access highway will improve its performance.

I-785 connects the Greensboro Region with Danville, VA. A portion of I-785 currently exists from I-40/ I--85 northward to U.S. 29. The existing U.S. 29 corridor will either be converted to a controlled-access facility or upgraded to interstate highway standards northward to Danville, VA. This will provide better connectivity from the Greensboro region to central Virginia.

I-685 will provide a better connection between the Greensboro and Fayetteville regions. It will follow the existing U.S. 421 corridor from I-85 in Greensboro southward through Siler City and Sanford before ending at the current interchange with I-95 in Dunn. A large portion of this corridor from I-85 to Sanford is already controlled-access but will still require upgrades to interstate highway standards. This connection will not only help commercial freight movement; it will also improve access from Sanford to Fort Bragg for the movement of military cargo.

From north to south, I-73 will begin at the NC-VA state line in Rockingham County and follow the existing route of U.S. 220 and N.C. 68 into the Triad. South of Greensboro, I-73 will again follow the U.S. 220 route into the City of Rockingham where it will utilize the right-of-way of U.S. 1 into South Carolina. From the west, I-74 will connect into I-77 in Surry County and utilize the existing U.S. 52 right-of- way to travel east into the Triad. It will then utilize the existing U.S. 311 route to connect into I-85 and continue onto the Future I-73. Interstates 73 and 74 will be coterminous between the cities of Randleman and Rockingham, where I-74 will split. At this point, I-74 will follow the U.S. 74 route into Wilmington, while I-73 continues southward into South Carolina.

Interstates 73 and 74 will improve access to the Port of Wilmington for shippers and carriers in the Triad. It will form a more direct route between the port and customers in the Midwest, particularly the cities of Cleveland, Columbus and Pittsburgh. As indicated by the travel shed analysis in Section 4.3.3, all of these cities are outside the 10-hour travel shed for the Port of Wilmington, limiting the ability of carriers to transport goods to the Midwest in a cost-efficient manner. The conversion of these routes to interstate highways should expand the boundaries of the port's travel sheds.

6.4 Long-Term Trends

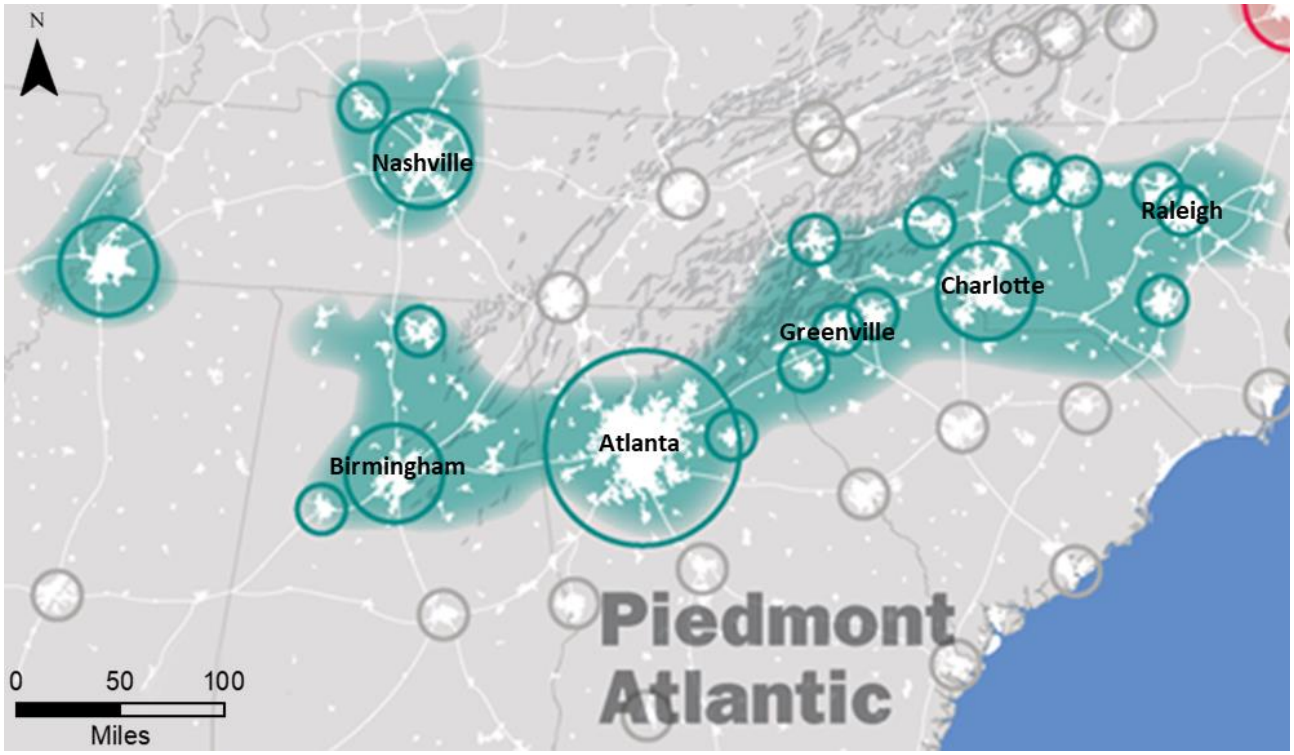
Numerous global, national, and statewide trends will continue to affect the performance and operation of the North Carolina highway system. Several trends were identified in the previous NCDOT studies including the *Seven Portals Study*, *2017 NCDOT Statewide Multimodal Freight Plan*, the *NC Moves 2050 Plan*, and the *Governor's Logistics Task Force Final Report*. These trends include continued statewide population growth, expansion of the Panama Canal, global shifts in manufacturing, the emergence of e-commerce fulfillment centers, and the advent of autonomous vehicles.

6.4.1 Emergence of Megaregions

As noted in the NCDOT *Seven Portals Study*, U.S. Census data indicate that a significant share of the nation's population is shifting from Northeastern and Midwestern states to Southeastern states including North Carolina. According to census data, population in the South Atlantic Region (which includes North Carolina) is expected to grow by nearly 31%t by the year 2030. Much of this growth will be centered upon the major metropolitan areas of North Carolina and other states.

As the nation's population continues to shift to concentrate in metropolitan areas, the emergence of megaregions will influence the movements of goods, people, and capital. The report, *America 2050: A Prospectus,* asserts that by 2050, megaregions will become the nation's new economic engines. These regions will act as semi-unified entities as their economies become increasingly linked. This linking of economies necessitates a corresponding linking of freight and other infrastructure assets to support economic and population growth. For the Piedmont-Atlantic megaregion (which includes North Carolina), much of the impact of an emergent megaregion will be concentrated along the I-85 corridor as evidenced in Figure 6.4.

FIGURE 6.4 PIEDMONT ATLANTIC MEGAREGION



Source: Regional Plan Association. America 2050. https://rpa.org/work/reports/america-2050-prospectus

6.4.2 Expansion of the Panama Canal

The addition of the third set of locks on the Panama Canal was completed in the summer of 2016 with the first vessel utilizing the expanded canal on June 26, 2016. With the addition, the Panama Canal now accommodates larger ships passing through this critical trade link between Asia and the U.S. east coast. This has generated new maritime traffic patterns and consequently, great expectations regarding opportunities for economic development. The new shipping services have led to concerns regarding port and inland infrastructure investments necessary to realize the potential local benefits of the expansion.

A potential major impact of the canal’s expansion is that the use of larger ships will reduce the per-unit shipping costs on longer-distance and high-volume trade lanes where economies of scale are largest. One such route is the Northeast Asia-U.S. trade lane, which represents one of the largest markets for the Panama Canal. Therefore, container ports on the U.S. east coast could realize significant increases in traffic over time due to the expansion.

Growth in containerized traffic at U.S. east coast ports would have significant implications for the highway system serving those facilities. Though a portion of seaborne freight will be transferred to the rail system upon arrival, a significant portion will be shipped to its final destination via trucks. The Port of Wilmington is connected to North Carolina’s largest metropolitan regions, Charlotte and the Triangle, via U.S. 74 and I-40. However, it is relatively remote from centers of freight demand relative to other ports on the U.S. East Coast. The completion of the conversion of U.S. 74 to I-74 will be important for providing additional accessibility to the Port of Wilmington and to position the port to capture future growth in seaborne trade.

6.4.3 Global Manufacturing Shifts

The combination of increasing wages in China and Southeast Asia and higher transportation costs has led to an increase in firms shifting manufacturing back to the United States, a trend known as reshoring. Locating production closer to U.S. consumers carries other advantages, such as allowing supply chains to be more responsive to changing consumer tastes and the ability to better manage disruptions. As a result, the U.S. has become a more attractive location for high-value manufacturing. Not only has this spurred U.S. companies to bring back certain manufacturing activities, but it has also increased the attractiveness of the U.S. for foreign direct investment from international firms.

The trend of reshoring along with foreign direct investment has created an opportunity for North Carolina to leverage its freight assets to improve its competitiveness in high-value manufacturing. The expansion of the state's interstate highway system along with improved rail service and connectivity to the Port of Wilmington makes North Carolina more desirable to these types of investments. Even without investment in the highway system beyond what has already occurred, North Carolina is a competitive state for reshoring and foreign direct investment. According to the Reshoring Initiative, North Carolina is fourth (behind South Carolina, Texas, and Tennessee) in the cumulative number of manufacturing jobs gained from 2010 to 2021 that resulted from reshoring or foreign direct investment.[5] With the planned increased investments in the highway system, especially the interstate system and roadways that provide access to major freight terminals (e.g. the Port of Wilmington, the CSX terminal at Rocky Mount, Charlotte-Douglas International Airport, etc.), North Carolina could surpass its southeast competitors.

6.4.4 Advent of Connected and Autonomous Vehicles

Much has been written regarding the potential for autonomous and connected vehicles (ACVs) to drastically alter the transportation landscape. Researchers have predicted that when the majority of the fleet is both connected and automated, there will be significant decreases in crashes, resulting in significant increases in safety and reliability. It will also lead to significant decreases in non-recurring congestion (e.g. incidents, work zones, weather, and special events), which accounts for about 50%of total congestion.[6] Decreased congestion provides the opportunity to get more capacity out of the existing system, lessening the need for expensive, time consuming capacity expansion solutions.

Though not discussed to the same extent as the implications of connected and automated vehicles for commuter trips, the implications of the technologies for goods movement are impressive. Commercial vehicles will likely be the earliest adopters of connected and automated vehicle technology given the intense pressures faced by the transportation industry. These include a shortage of commercial vehicle drivers that is likely to worsen over time, pressure from shippers to reduce costs and increase reliability, and increasing demand that is expected to continue well into the future as the tonnage of freight moved on the multimodal freight system steadily grows. These forces combined with a growing population that will demand more goods create an environment in which North Carolina's highways are likely to facilitate automated cargo-carrying heavy trucks in the future. NCDOT teamed with Volvo and FedEx in 2018 to study truck platooning that used a wireless communication system to connect the vehicles

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[5] Reshoring Initiative. *Reshoring Initiative Data Report*, 2021. https://reshorenow.org/content/pdf/2021_RI_data_report.pdf

[6] FHWA. Office of Operations. http://ops.fhwa.dot.gov/program_areas/reduce-non-cong.htm

and match the pace of the lead truck.[7] Subsequent operations of automated vehicles on I-10 between Texas and Arizona are proving the commercial and operational viability of these vehicles.[8]

6.5.5 E-Commerce and Fulfillment Centers

A 2022 FHWA study identified e-commerce as one of five key global logistics trends impacting U.S. freight flows[9]. The COVID-19 pandemic further accelerated the share of sales through e-commerce. As same-day and next-day delivery has become the norm for e-commerce transactions, retailers have begun to reposition regional and smaller distribution centers closer to urban areas – the centers of demand. Delivery on such a short time frame is expensive, although necessary, as customers have come to expect this level of service. Strategically placed fulfillment centers allow firms to deliver the level of shipping service that consumers demand while maintaining relatively affordable costs.

In the Triangle, Amazon leased nearly 325,000 square feet of distribution space along T. W. Alexander Drive in Durham (near the Research Triangle and Raleigh-Durham International Airport) to accommodate growing demand in central North Carolina.[10] Amazon built a major regional fulfillment center in Garner and a cross-dock facility in Johnston County to support the increased volume of business in the Triangle and further east. This is in addition to space in Raleigh that Amazon already leases to support its same-day Amazon Prime service and a distribution center in Concord in the Charlotte region.

The emergence of e-commerce and its supporting infrastructure will affect the North Carolina freight system by increasing the importance of freight system reliability and the frequency of truck trips in urban regions that employ smaller vehicles. For example, an e-commerce fulfillment will generate multiple incoming truck trips from larger facilities (in the case of Amazon's Concord facility, trucks will likely travel up I-85 from their larger facility in Spartanburg, SC) to serve local demand. It will also generate significant numbers of outgoing truck trips as smaller packages and parcels are delivered to consumers.

The portion of the highway network serving rail intermodal facilities, such as those in Charlotte and Rocky Mount, will be impacted as re-stocking shipments for the e-commerce fulfillment centers utilize rail intermodal service. To support the coordination of intermodal facilities with e-commerce fulfillment centers, the highway network linking the two freight terminals must provide reliable performance if shippers are to develop schedules based on the level of service provided by these highway links. Reliability directly affects shipping costs and the ability of retailers to meet consumer demand.

[7] https://www.tarpo.org/2018/06/new-truck-platooning-technology-showcased-in-north-carolina/

[8] https://techcrunch.com/2021/12/29/tusimple-completes-its-first-driverless-autonomous-truck-run-on-public-roads/

[9] https://www.transportation.gov/sites/dot.gov/files/2022-03/EO%2014017%20-%20DOT%20Sectoral%20Supply%20Chain%20Assessment%20-%20Freight%20and%20Logistics_FINAL_508.pdf

[10] http://www.bizjournals.com/triangle/blog/real-estate/2016/07/amazon-signs-lease-for-rtp-warehouse.html

7.0 HIGHWAY FREIGHT CHALLENGES AND OPPORTUNITIES

While future analysis will focus on identifying specific deficiencies and needs, this section presents key global challenges and opportunities in three areas: (1) mitigating the impacts of traffic volume growth on the state's system, (2) facilitating economic development by improving connectivity to the state's seaports and intermodal freight terminals, and (3) developing a plan of action for handling commercial ACVs. Addressing these needs will help the highway freight system to sustain the ability to serve trucks and enable future economic growth in North Carolina.

7.1 Mitigate the Impacts of Increased Traffic Volumes on the Highway Freight System

Based on the results of the NPMRDS data, though most of the state system provides for uncongested and reliable truck travel, there are portions of the system where performance is challenged. These are mostly located in North Carolina's major metropolitan areas. The results of the statewide travel demand model indicate that traffic volumes on North Carolina highways are predicted to grow by a substantial amount, which will result in capacity-constrained conditions on several corridors that are important to freight mobility. Furthermore, FAF45 projections suggest the highway system will remain the predominant mode by which freight is moved through and within the state. Mitigating the effects of growth, especially on corridors with existing challenges, is important for moving forward.

Corridors with existing challenges that may be exacerbated by growth include the I-40 and I-440 corridors near Raleigh. Also within the Triangle are challenges along I-540 near its interchange with I-40 and N.C. 540. In the Charlotte region, existing congestion and reliability issues along I-77 through the core of the region and north of the I-485 perimeter may be worsened by traffic volume growth. The southwest portion of I-485 (between U.S. 74 and I-85) could be targeted for initiatives meant to mitigate the impacts of growth. In the Triad, existing performance issues on the Future I-285 and I-40 corridors could be exacerbated by traffic volume growth.

Since key truck and freight corridors also serve as major commute corridors, solutions to address existing and future congestion and reliability must address both passenger traffic and freight. With changing technologies and new and enhanced modes of transportations being developed, alternative modes are likely to be more effective and efficient at addressing congestion. One can no longer simply think about adding more lanes to address future congestion. Therefore, as recommendations are developed for this effort, the role that technology will play in shaping the future of transportation will be considered.

7.2 Improve Connectivity to Major Freight Terminals

The adage that the last mile is the toughest mile is particularly relevant to goods movement. As shown by the results of the truck mobility and travel time reliability analyses in Sections 4.2 and 4.3, the long-haul portions of truck trips primarily occur over highways that provide high levels of reliable, congestion-free travel. However, as motor carriers approach their pick-up or delivery locations, especially within major metropolitan areas, they face significant congestion and uncertainty in highway system performance, which greatly affects the last mile. For motor carriers, this marks the difference between their ability to travel from south to north, or from the east to west portion of a region in time to meet their delivery windows. This translates into increased transportation costs in terms of labor and time.

To address last-mile issues throughout the state, NCDOT should assess last-mile connectivity to major freight terminals. Connectivity between the NHS and major freight terminals is in part achieved through the FHWA's intermodal connectors program. NHS intermodal connectors are roadways (often of lower functional classifications) that provide first and last-mile access to one or more freight-serving facilities: airports, marine ports, pipeline terminals, and rail intermodal terminals. While intermodal connectors generally reflect the predominant routes trucks operate to access these facilities, they can be outdated as new routes are constructed or changes to the physical layouts of the terminals require the use of alternative roadways. Freight-serving intermodal connectors should be reviewed to assess their usage and performance as an important element of promoting freight mobility and accessibility.

In addition to assessing performance and usage of NHS intermodal connectors, roadways that serve as first and last-mile connectors to major freight generators not included in the NHS intermodal connectors program should be considered in an assessment of last-mile connectivity. Significant truck volumes can be generated from freight-related economic clusters (i.e., areas with large numbers of manufacturing transportation/warehousing facilities, among others) including logistics-based commercial developments. Identifying these roadways, monitoring their performance, and making the appropriate investments would help improve statewide freight mobility and promote economic development.

7.3 Plan for Autonomous and Connected Commercial Vehicles

While much attention has been given to the companies behind the development of ACVs, such as Google, Tesla, and Uber as well as traditional automotive manufacturers, little attention has been given to companies charged with creating and maintaining the infrastructure on which those vehicles must operate: the public sector. The advent of self-driving vehicles raises important questions about their potential effects on travel behavior, land use, and safety as they fundamentally restructure the driving task. Particularly for freight, questions arise about how autonomous heavy trucks will be deployed and the use of lighter, smaller commercial vehicles to facilitate the on-demand economy.

To prepare for the impending reality of connected and automated heavy trucks and other commercial vehicles on North Carolina highways, NCDOT has convened a task force and issued initial reports on how these vehicles are likely to change the way the department conducts business. ACV use will change the manner in which the highway system operates and performs; thus, current planning processes and analytical methodologies need to be expanded for handling these new roadway users. Heavy trucks deploying this technology will likely progress from manual platoons to fully automated platoons and ultimately, standalone automation.[11] Manual platoons would be characterized by multiple trucks operating in tandem with crash prevention and fuel saving measures implemented through ACV technology. The trucks would still be operated by drivers. The next step would be fully automated platoons, which would employ a driver at the lead of the platoon with driverless trucks following. The last step in the deployment of the technology would be fully automated trucks operating without drivers.

As consumers increasingly participate in e-commerce, they are also increasingly demanding that purchased items be delivered faster at less cost. Lighter trucks and commercial vehicles may play a key role in helping retailers and carriers meet the expectations of the on-demand economy. With the enabling technologies for self-driving vehicles, these commercial vehicles could be deployed frequently and inexpensively for urban deliveries. However, it may translate to increased vehicle-miles traveled as some researchers have more broadly predicted across trip purposes.[12, 13]

Going forward, NCDOT should continue to plan and prepare for autonomous vehicles. Preparing for commercial ACVs requires NCDOT to review and enhance its analytical capabilities to develop a foundation for capturing the effects of self-driving vehicles on capacity demand, driver behavior, and roadway safety. It also includes examining the infrastructure needed to safely facilitate these connected and autonomous vehicles on state roadways (such as fiber networks) and the abilities of staff to manage changing technologies increasingly large data sets.[14] If possible, NCDOT should attempt to partner with vehicle manufacturers and technology companies for experimenting with ACVs. NCDOT should coordinate with other state agencies such as the North Carolina Department of Motor Vehicles (NCDMV) to begin discussing the regulatory framework by which automated commercial vehicles will be governed. This includes examining issues such as licensing for commercial ACVs and electronic security.

[11] Peloton Technology, 2016. *Connected Automated Trucks*. Proceedings of the Automated Vehicles Symposium, San Francisco, CA, July 19-21, 2016. Association for Unmanned Vehicle Systems International and the Transportation Research Board.

[12] Fagnant, D. J., Kockelman, K. 2014. “The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios.” *Transportation Research Part C: Emerging Technologies* 40, pp. 1-13.

[13] Fagnant, D. J., Kockelman, K. 2015. “Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations.” *Transportation Research Part A: Policy and Practice* 77, pp. 167-181.

[14] Zmud, J. et al., 2015. *Paths of Automated and Connected Vehicle Deployment: Strategic Roadmap for State and Local Transportation Agencies*. http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/161504-1.pdf.