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# Access in Appalachia

## PILOT STUDY

## Sponsored by:

**Appalachian Regional Commission**

## Led by:

**North Carolina Department of Transportation**

## Prepared by:

**VHB and EBP**

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# Executive Summary

## Introduction

North Carolina communities are connected to opportunity by the state's multimodal transportation system. A well-connected transportation system allows more people to access and participate in the economy. The strength of our communities and overall economic potential depends on reliable access for all. The Access in Appalachia Pilot Project, which extended beyond the Appalachian Region to the entire state of North Carolina, provided an opportunity to measure differences in accessibility across the state and develop replicable metrics to aid in transportation project prioritization, planning activities, and policy development.

### Goals and Objectives of this Report

The strength of our communities and overall economic potential depends on reliable access for all. The goals of the North Carolina Department of Transportation's (NCDOT's) accessibility pilot project are:

- Build upon the Appalachian Regional Commission's (ARC's) *Access in Appalachia: Concept and Methodologies* research to support transportation prioritization, planning, and policy in North Carolina (Seiber et al., 2020a).
- Measure existing access in North Carolina across modes.
- Connect measures of access to indicators of relative need to identify locations with the greatest opportunity for improvement through targeted transportation investments.
- Define aggregated "super-metrics" that enable the comparison of access statewide and across modes.
- Outline the ways in which access measures may support future transportation planning in North Carolina.

### Research Audience

This research is intended to be used by practitioners at state, regional, and local transportation agencies, as well as economic development councils. Analysts new to the concept of access can use the maps and data to identify needs for their community, while more experienced analysts can use the metrics to screen potential project impacts and test different scenarios.

### Definition of Access

Access refers to the ability of people and businesses to reach activities, services, and goods given available transportation options. It is a way of quantifying how many, and how quickly, activities are reachable within a given level of effort. Access addresses not only where people or goods currently travel, but the potential or opportunity for interaction, based on where they could travel. Accessibility levels depend on (1) how many destinations are within a certain area and (2) a person's (or shipment's) level of mobility, or ability to travel between places. This research considered statewide access – including access to destinations outside of North Carolina – across five modes, as shown in Figure E1.

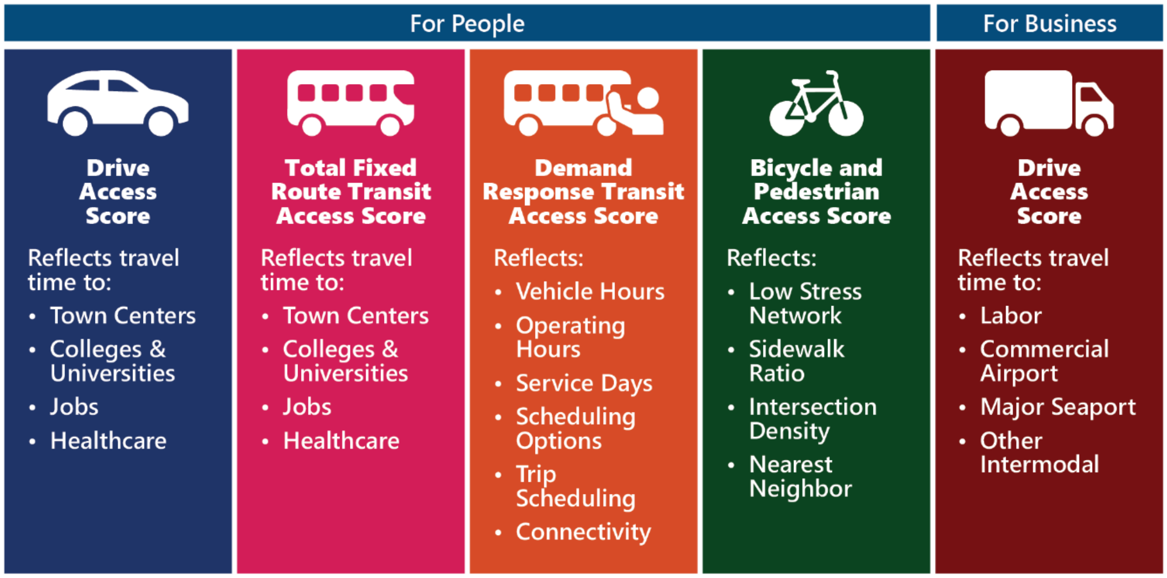


Figure E1. Access for People and Business in North Carolina

## Definition of Opportunity

Access metrics alone do not support decision-making. All communities could benefit from greater access to amenities, but understanding where the greatest opportunity for improvement exists requires comparisons across the state, between modes, and across demographic groups. This research defines opportunity as the intersection of (a) where access is lacking, and (b) where community need is greatest (Figure E2). Access metrics are benchmarked to compare access statewide and identify communities facing the greatest challenges. Need metrics use demographic and economic data to identify communities for whom access is particularly important due to historical and ongoing transportation or economic disadvantage. Opportunity then combines these two concepts to focus on areas with relatively low access and high need (refer to Figure 14 and Figure 32 as examples of this for drive time in the report).


Figure E2. Opportunity – Focusing on Low Access and High Need

## Accessibility Calculations

Based on a scan of relevant research, the drive time and fixed-route transit-time access metrics for people and business in this project focus on the accessibility of destinations. This is calculated using one of two functional forms: 1) distance decay function; and 2) nearest destinations. For demand response transit and non-motorized access, access metrics are focused on level of service and network quality (Figure E3).

| | For People | | | | For Business |
|---|---|---|---|---|---|
| Measurement Approach | Drive Access Score | Total Fixed Route Transit Access Score | Demand Response Transit Access Score | Bicycle and Pedestrian Access Score | Business Drive Access Score |
| Network Travel Time | ☑ | ☑ | | | ☑ |
| Service and Network Quality | | | ☑ | ☑ | |
| Distance Decay Function | ☑ Town Centers, Colleges and Universities, Mental Health, Substance Abuse, Urgent Care, Jobs | | N/A | N/A | ☑ Workforce |
| Nearest Destination | ☑ Hospitals (nearest) | | N/A | N/A | ☑ Multimodal terminals (nearest 2 of each kind) |

**Figure E3. Accessibility Framework for each Mode**

### Distance Decay

The decay function is used for situations in which having access to more than one of a given destination (like a job or an urgent care center) can be beneficial. This approach counts destinations that people can reach within a certain travel time by car or fixed-route transit. This further prioritizes closer destinations over further ones (Figure E4).

**Figure E4. Example of How the Distance Decay Function Prioritizes Closer Destinations**

## Nearest Destination

The nearest destination approach is used where access to only one or two of a given destination is sufficient and people are less likely to consider options located further away. This applies to destinations where more is not necessarily better (like a hospital), and basic access is the focus (Figure E5).

**Figure E5. Example of How the Nearest Destination Function Prioritizes the Closest Destination**

# Enhancing Multimodal Access & Key Findings

The data and findings from the Access in Appalachia Pilot study can be used to assess disparities in access to key destinations, as well as opportunities where transportation investments could be most impactful. The following sections underscore the key findings from this pilot study, as well as how the research can be used in the future.

## Access and Need

This research provides a framework for contextualizing both access and need. The communities where access is low and need is high should be a focus for future improvements. The research revealed that levels of access across travel modes vary greatly across the state and by community. Generally, urban communities in North Carolina tend to have greater access to destinations than those in rural areas. The same is true in the Appalachian Region of the state; however, the Appalachian Region tends to have lower access to destinations than similar locations elsewhere in the state (Figure E6), highlighting that disparities vary by context. Furthermore, persons without access to a vehicle are substantially disadvantaged over those who have access to a personal vehicle.

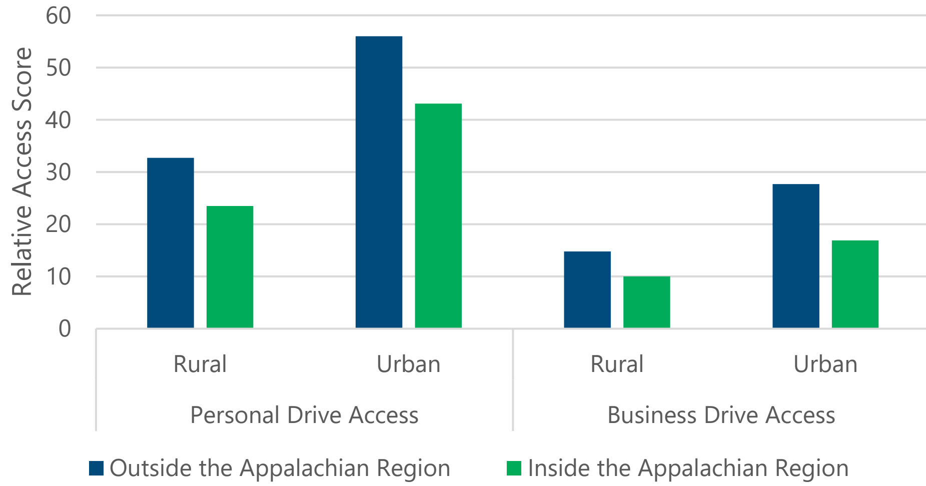


**Figure E6. Comparison of Average Personal and Business Drive Access Scores across Communities in North Carolina[1]**

## Geographic Scope and Study Area

This research incorporated destinations, demographics, and travel conditions beyond the state's borders to develop a more comprehensive assessment of access. This approach considered spillover effects and reduced uncertainty around state boundaries that are typically not considered in current project prioritization. Furthermore, this effort represents the first time that fixed route transit service was compiled for the entire state.

## Multimodal Scope and Policy Support

This research assessed five different travel modes (see Figure E1) using metrics that support potential policy decisions for each mode. Each set of metrics measure level of service and are unique to that mode and relevant to the business of NCDOT, regional planning agencies, and local governments.

## Equity and Impact on Specific Populations

This research considered relevant communities and populations where improvements in access could be most profound. For instance, the opportunity metric for personal travel considered the Transportation Disadvantage Index (TDI) as an indicator where greater access is most needed. For drive time access for business, county-level economic distress metrics highlighted communities where business-oriented need for greater access is highest.

## Impacting Access and Opportunity in Project Programming

This research proposed four approaches for cross-modal comparison and assessing needs for multiple modes. Each approach can be used to answer key questions about North Carolina's transportation network, and ultimately support transportation planning decisions. There are many project types and

[1] Note that scores are not necessarily comparable between modes, and the figure should only be used to compare within a single mode.

categories, such as increased transit service hours or sidewalk connections, that would affect the modal metrics incorporated in this research. These could produce quantifiable impacts that would improve a community's access.

## How to Use the Research

The Access in Appalachia Pilot project has practical application for transportation planners and engineers in the state. North Carolina's current project prioritization process, the Strategic Prioritization Office of Transportation (SPOT) Strategic Transportation Investments (STI) process, focuses on the narrow impacts of proposed projects. However, it does not evaluate the following key components of planning:

- The current level of access to destinations available to communities affected by the project.
- The relative level of need of communities affected by the project.
- The value of projects to different communities based on the current level of access relative to the need for greater access.

This research is intended to support that process. The following use cases, based on the key findings of this research, provide a framework for how practitioners can consider this research in their decision-making process.

- Analysts can use the access and opportunity scores to prioritize potential projects in areas where access is low and need is high and measure potential improvements.
- Access and opportunity scores are available for all communities in North Carolina. Analysts can filter and scale the score by different geographies for various needs:
  - Urban/Rural context
  - Appalachian Region
  - NCDOT Division
  - Metropolitan or Rural planning organization (MPO or RPO)
  - County
  - Municipality

  Since scores are based on statewide totals, scores can be compared to the statewide average, to peer locations in the state (e.g., urban areas), or to the analyst's jurisdiction.
- The research underscores the disparity in access between different modes (*Multimodal Scope and Policy Support*). The metrics and data in this research provide a path for analysts to assess improvements in levels of access as a result of multimodal projects and policies, as well as provide the justification for why multimodal improvements are necessary (especially for persons with limited access to a personal vehicle).
- Opportunity metrics consider transportation disadvantage and communities that face traditional barriers to access (*Equity and Impact on Specific Populations*). The data produced by this research can support assessments of equitable access in North Carolina.
- The research identified data inputs and remaining data needs that support accessibility metrics in the state. Decision makers should prioritize accessibility metrics that support the planning process.

# 1

## Introduction

North Carolina communities are connected to opportunity by the state's multimodal transportation system. However, there are big differences between the largest well-connected urban areas and more rural areas where access to opportunities and services is limited. Nearly a third of North Carolina's 100 counties are part of the Appalachian Region. Beyond Appalachian counties in the west, rural counties in the eastern part of the state share similarities in terms of lower population density and transportation access barriers. Economies thrive when a well-connected transportation system allows more people to access and participate in the economy. The Access in Appalachia Pilot Project, which extended beyond the Appalachian Region to the entire state of North Carolina, provided an opportunity to measure differences in accessibility across the state and develop metrics to aid in transportation project prioritization, planning activities, and policy development.

# Goals and Objectives of this Report

The strength of our communities and overall economic potential depends on reliable access for all. Using the appropriate metrics to review and positively align strategic transportation investment can promote transportation accessibility benefits—whether traveling by private vehicle, public transit, or walking and biking—for all North Carolinians.

The goals of the North Carolina Department of Transportation's (NCDOT's) pilot project are to:

- Build upon the Appalachian Regional Commission's (ARC's) *Access in Appalachia: Concept and Methodologies* research to support transportation prioritization, planning, and policy in North Carolina (Seiber et al., 2020a).
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- Connect measures of access to indicators of relative need to identify locations with the greatest opportunity for improvement through targeted transportation investments.
- Define aggregated "super-metrics" that enable the comparison of access statewide and across modes.
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# Definitions and Framework

## Access

The *Access in Appalachia* research assessed existing access in North Carolina to key household and business destinations. This research viewed "access" through the lens of personal or business access to education, employment, healthcare (including mental health facilities, substance abuse centers, hospitals, and urgent care offices), town centers, intermodal freight facilities, commercial seaports and airports, and labor pools. To thrive, people and businesses require access to these destinations for important goods, services, and economic opportunities.

This research considered statewide access – including access to destinations outside of North Carolina – for five modes, as shown in Figure 1. In the case of drive access and fixed route transit access, metrics directly reflect travel time on the network to the identified destinations. Demand response and bicycle and pedestrian access scores reflect the relative availability and quality of access using alternative metrics that do not directly reflect travel time. Access is measured for every Census block group in the state.

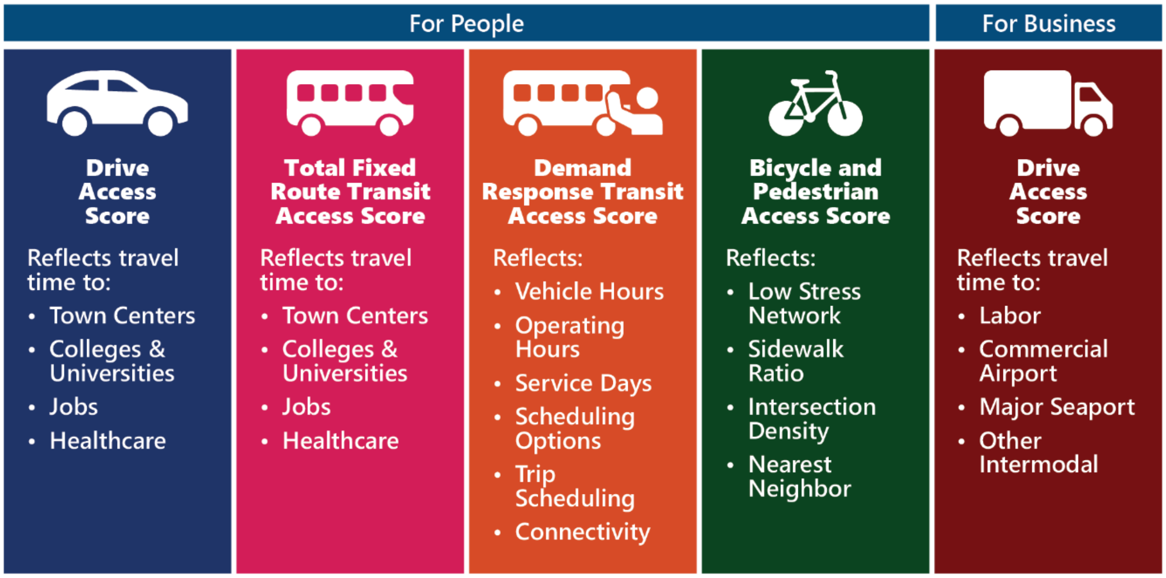


Figure 1. Access for People and Business in North Carolina

## Opportunity

Access metrics alone do not support decision-making. All communities could benefit from greater access to amenities, but understanding where the greatest opportunity for improvement exists requires comparisons across the state, between modes, and across demographic groups. This research defines opportunity as the intersection of (a) where access is lacking, and (b) where community need is greatest (Figure 2). Access metrics quantify how well current transportation infrastructure or services connect people and businesses to opportunities. Access metrics are benchmarked to compare access statewide and identify communities facing the greatest challenges. Need metrics use demographic and economic data to identify communities for whom access is particularly important due to historical and ongoing transportation or economic disadvantage. Opportunity then combines these two concepts to focus on areas with relatively low access and high need.


Figure 2. Opportunity – Focusing on Low Access and High Need

## Application to NCDOT Project Prioritization, Planning, and Policy

The products of this research are a suite of datasets and maps that can be used to support NCDOT project prioritization, planning, and policy discussions. This report presents specific recommendations for:

- Metrics that capture access to multiple destinations by a given mode,
- Approaches to aggregating and comparing across modes, and
- Methods for incorporating the research finding into the Strategic Transportation Investments (STI) prioritization process.

Disaggregated data by destination or mode may further support other types of analysis to support planning and policy discussions statewide or by other planning partners at the regional or local level.

# Report Organization

The remainder of this report includes the following chapters:

- Chapter 2 describes prior plans and research.
- Chapter 3 summarizes the data identified and employed in the analysis.
- Chapter 4 provides detail on the access and opportunity analysis process.
- Chapter 5 presents approaches for comparing access metrics across modes and potential implementations.
- Chapter 6 outlines potential approaches for enhancing multimodal access and key findings.
- Chapter 7 discusses future data needs.

# 2

# Research and Background

This chapter summarizes background research and concepts that informed this project.

## ARC Access in Appalachia: Concept and Methodologies – Final Report (2020)

The ARC is an economic development agency of the federal government and 13 state governments focusing on 423 counties across the Appalachian Region, including 31 counties in North Carolina. ARC's mission is to innovate, partner, and invest to build community capacity and strengthen economic growth in Appalachia to help the Region achieve socioeconomic parity with the nation.

Accessibility is intrinsically linked to economic development and opportunity. The 2020 study defined access in a way that is relevant to needs and concerns in Appalachia, outlined measurement approaches that capture key dimensions, and presented a vision for applying those measures across the entire Appalachian Region. The study results were published as both a Technical Report (Seiber et al., 2020a) and as a Primer (Seiber et al., 2020b) for decision-makers.

The study documented in this report is one of multiple pilots funded by ARC with its partners to implement concepts developed in the original research. The following sections provide an overview of key findings from the *Access in Appalachia* research.

### Three Dimensions of Accessibility Measurement

Accessibility refers to the ability of people and businesses to access desired activities, services, and goods with their available transportation options. As a performance measure, accessibility helps decision-makers answer the question: *Do transportation and land development conditions meet the needs of people and businesses, enabling full and equitable participation in the economy and society?*

Comprehensive accessibility definitions address the three key dimensions shown in Figure 3.

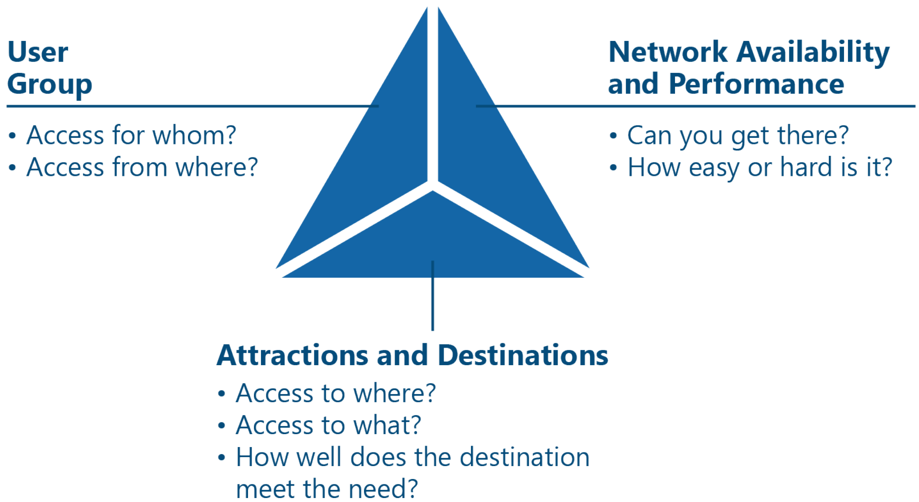


Figure 3. Three Dimensions of Accessibility Definition

## Recommended Accessibility Metrics

The recommended metrics from the *Access in Appalachia* Report are organized by perspective and include:

- Metrics for businesses, capturing key items that businesses need to access in order to thrive,
- Metrics for people, addressing the needs of individuals, and
- Metrics for technology that are relevant to both businesses and people, addressing the ability of broadband to bridge gaps where physical access is poor.

### Metrics to Capture Business Access Needs

The following set of core metrics was selected as being directly relevant to economic development outcomes. The business specification in the first column of Table 1 describes the industries for which a particular type of access is most critical. For example, access to labor is important to all industries, while access to rail facilities may be most important to manufacturing and trade and warehousing sectors.

### Table 1. Suggested Core Metrics for Businesses[2]

| Business Specification | Access To … | | Destination Specification |
|---|---|---|---|
| All | **B1. Labor** | | Associate's degree or Higher |
| Manufacturing (31-33) | **B2. Supply Chain** | | Employment |
| All | | | |
| Trade and Warehousing (42-49) | **B3. Delivery** | **Consumers** | Population |
| Manufacturing and Trade and Warehousing (31-33, 42-49) | **B4. Intermodal Connectivity** | **A) Rail Facility** | All Freight Rail Facilities |
| Manufacturing and Trade and Warehousing (31-33, 42-49) | | **B) Port** | Coastal Port |
| All | | **C) Airport** | All |

## Metrics to Capture People's Access Needs

People have different accessibility needs, which also vary by population group. The following set of core metrics was selected to encompass the economic development purpose of accessibility (Table 2).

### Table 2. Suggested Core Metrics for Population

| Population Specification | Access To … | | Destination Specification |
|---|---|---|---|
| Age 18–65 | **P1. Jobs** | | Employment |
| Age 18–24 | **P2. Education** | **College** | All |
| All | **P3. Health Care** | **A) Primary Care** | General Practice |
| | | **B) Trauma Center** | All |
| | | **C) Addiction Treatment Center** | All Substance Abuse |
| All | **P4. Town Centers** | | All |
| All | **P5. Tourist Destination** | | National and State Designated |

## Metrics to Capture Broadband Access

Broadband internet can assist in bridging gaps where physical accessibility is insufficient for any groups of the population. Table 3 shows the sufficient technology to serve this purpose.

[2] Numbers refer to North American Industry Classification System (NAICS) industry codes.

Table 3. Suggested Core Metrics for Technology

| Access To … | Sufficient Speed and Technology |
|---|---|
| **T1. Mobile Broadband (Cell Phones)** | LTE |
| **T2. Fixed Broadband (At Home)** | ≥ 25/3 MBPS Download/Upload<br>(benchmark defined by the Federal Communications Commission) |

## Recommended Methodologies to Build the Metrics

The *Access in Appalachia* Report suggests the following outline of methodologies for building the metrics:

- *Geographic Unit*: The study recommends using a pre-defined standardized geography. For adequate granularity, the report suggests using the smallest Census unit with generally available data, the block group.
- *Representative Origin and Destination Points*: Calculations of travel times require that each block group have an assigned point within it to serve as the start or ending point for measurement. The study suggests that the points be either the population- or employment-weighted centroids.
- *Functional Form of Measures*: For rural Appalachia, the application of time decay functions, where more distant destinations are considered with a lower weight, are the preferable accessibility function for most metrics. The steepness of this decay can be calibrated to different trip purposes based on observed behavior. A nearest destination approach is more appropriate for some destinations such as trauma centers, where access to additional destinations after the first one that can be reached is not meaningfully better.
- *Importance of Destinations*: For some metrics, the importance of the destination is measured by counts of people or jobs, but for other metrics individual potential destinations need not be weighted by importance (e.g., trauma centers of a certain level are equals).

## Concept for Aggregating Modal Options into One Metric

*Access in Appalachia* suggests making use of information about various modes in the following way:

- With most people in Appalachia relying on cars for their mobility, car accessibility will be of great importance in the assessments and should be scored and mapped individually.
- However, some households do not have enough cars for everybody to rely on car availability all the time or they do not have any car at all. Information about carless or various degrees of car-poor households may portray the level of car availability by geographic area.
- Multimodal accessibility can be represented by aggregating all three modal accessibility scores (using each mode's respective travel times) according to the share of the population affected. Car accessibility would be weighted by the proportion of the population that has access to a car while transit or walking (depending on availability) would be weighted by the share of carless and car-poor households for whom driving is not a meaningful option. This would yield an overall weighted multimodal accessibility score (Figure 4).

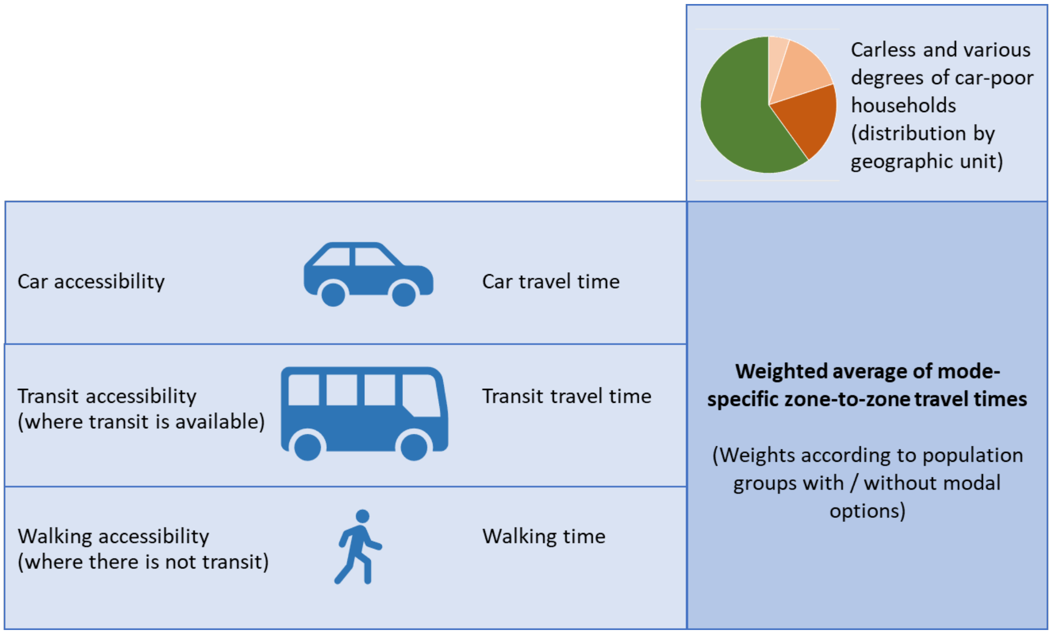


Figure 4. Aggregating Modal Options into One Multimodal Travel Time

It should be noted that the use of walking as the fallback mode represents a significant penalty for areas without transit due to slow walking speeds. Many people without access to cars in an area without transit may find other options for their trip (e.g., car-sharing, ride hailing, and biking) that are faster, but walking is universally seen as the option available to almost everybody. However, walking instead of driving or using transit limits distance and reduces accessibility.

## ITRE Accessing Measures of Transportation Disadvantage for Public Transportation Project Prioritization (2019)

The Institute for Transportation Research and Education (ITRE) and NCDOT completed RP 2019-16, which focused on measures of transportation disadvantage for public transportation project prioritization (Gaustad et al., 2019). The purpose of the study was to identify metrics that represent transportation disadvantage and to use them to guide disbursement of public transportation funds within North Carolina.

The report recommended the following metrics be combined into a single rubric/score sheet representing transportation disadvantage:

1. Transportation Disadvantaged Populations,
2. Access to Points-of-Interest,
3. Transportation Service Provision,
4. Need for Service,
5. Improved Connectivity and Multimodality, and
6. Alleviation of Project-Specific Barriers.

The literature review performed as part of the study identified the socio-demographic groups most frequently identified as “transportation disadvantaged populations” based on a review of 40 relevant sources, as noted in Table 4.

Table 4. Socio-Demographic Groups Included in the 40 Most Relevant Sources as Transportation Disadvantaged Populations

| Rank | Demographic Group Included | Number of Sources Citing | Percentage |
|---|---|---|---|
| 1 | Low-Income | 32 | 80% |
| 2 | Elderly | 19 | 48% |
| 3 | Minorities | 15 | 38% |
| 4 | Disabled (General) | 13 | 33% |
| 5 | Adolescents | 11 | 28% |
| 6 | Carless | 11 | 28% |
| 7 | Disabled (Physical) | 9 | 23% |
| 8 | Women | 8 | 20% |
| 9 | Limited English Proficient (LEP) | 7 | 18% |
| 10 | Age (General) | 6 | 15% |
| 11 | Disabled (Cognitive) | 6 | 15% |
| 12 | Foreign-Born | 3 | 8% |
| 13 | Rural | 2 | 5% |
| 14 | Other or Uncategorized | 12 | 30% |

Source: Gaustad et al., 2019.

## Richmond Multimodal Network Equitable Access Study: Transportation Technology Accessibility (2022)

The *Richmond Multimodal Network Equitable Access Study* explored barriers and impacts related to multimodal transportation access in the City of Richmond, Virginia, using data-driven performance metrics (City of Richmond, 2022). It not only looked at access to economic activity, but social and community access as well.

This study built on common forms of accessibility metrics with the objective of understanding the demographic composition of residents in a given zone, how demographic characteristics influence daily travel needs and which destination types are most relevant to different people, as well as how they influence daily travel budgets and what costs over the network are bearable for different travelers. The study also sought to provide analysis methods to allow facility attributes and conditions to influence estimated costs for travelers, weight destinations reachable by travel costs and relevance to travelers for a demographically-informed estimate of accessibility, and estimate the number of relevant competitors that can reach destinations to normalize access at a zone interchange (origin-destination) level. The study then combined estimates of access to types of destinations into a composite score for a given travel mode and trip purpose.

The study estimated accessibility by mode for walking, biking, driving, and transit to a range of destinations, as summarized in Table 5. Composite accessibility scores measure the number of reachable destinations while accounting for destination relevance and travel time tolerance (i.e., varying decay functions) for different demographic groups. Proximity scores describing the ease of accessing important destinations via non-routine travel. The proximity scores simply report the travel time to the nearest "crisis" destination.

**Table 5. Accessibility Estimates and Scores Considered as Part of Richmond Equitable Access Study**

<table>
<tr><th>Independent Accessibility Estimates</th><th>Composite Accessibility Scores</th><th colspan="2">Proximity Scores (Extenuating Circumstances Destinations)</th></tr>
<tr><td rowspan="3">Walking</td><td rowspan="3">Work</td><td rowspan="3">Emergency Services</td><td>Police Stations and Sheriff Facilities</td></tr>
<tr><td>Fire and EMS Stations</td></tr>
<tr><td>Urgent Care Facilities</td></tr>
<tr><td>Biking</td><td>Shopping</td><td rowspan="5">Other</td><td>Cooling Stations</td></tr>
<tr><td>Driving</td><td>School</td><td>Shelters for Persons Experiencing Homelessness</td></tr>
<tr><td rowspan="3">Transit</td><td>Community</td><td>Food Pantries</td></tr>
<tr><td>Social and Recreation</td><td>Social Services</td></tr>
<tr><td>Health Care</td><td>Polling Places</td></tr>
</table>

To understand equity of access, the study compared average accessibility available to different segments of the population. The study summarized access across the City of Richmond for people of different races (white and black, indigenous, and persons of color – BIPOC), ethnicities (Hispanic vs. non-Hispanic), income levels (low-income vs. non-low-income), and vehicle ownership (zero-car households vs. households with at least one vehicle).

The study investigated the prevalence of technologies that facilitate transportation access using a combination of data from the U.S. Census Bureau's 2019 five-year American Community Survey (ACS) results and the City of Richmond's 2021 Paths to Equity (PTE) survey. Technology metrics considered include:

- Broadband,
- Access to Internet at Home,
- Smartphone Ownership,
- Access to Phone Data Plan,
- Credit and Debit Cards, and
- Bank Accounts.

Outcome Linked Accessibility Metrics were also examined in the categories of health, income, residential multimodal commute patterns, and development activity density (Table 6).

Table 6. Outcome Linked Measures and Accessibility Indicators

| Evaluated Measures | Accessibility Indicators |
|---|---|
| **Public Health** | Clinical Health Conditions<br>Environmental Factors<br>Health Outcomes (Health Maintenance, Pulmonary Health, Oral Health, and Physical Health) |
| *Data Sources: Center for Disease Control (CDC) Population Level Analysis and Community Estimates (PLACES); Virginia Department of Health (VDH) Health Opportunity Index (HOI).* | |
| **Household Income Patterns** | Household Income<br>Median Income<br>Income Inequality |
| *Data Sources: 2019 5-Year ACS.* | |
| **Residential Commuting Patterns** | Commute Mode<br>Time Spent |
| *Data Sources: 2019 5-Year ACS.* | |
| **Development Activity Density** | Vehicle Ownership<br>Activity Density and Intensity<br>Walkability<br>Transit Service<br>Infrastructure Development<br>Worker-Job Balance |
| *Data Sources: Smart Location Database (SLD).* | |
| **Gentrification** | Common Indicators of Neighborhood Change<br>Displacement from Gentrification<br>Previous Multi-Modal Projects in Richmond |
| *Literature Review.* | |

Finally, the relationship between tested measures and accessibility indicators was examined to find locations where expectations of mode usage did not match with the realities found there. From this, it was found that populations in areas with a higher non-automobile mode share were typically more diverse, but more vulnerable than other populations. This led to an examination of barriers to accessibility, as well as how wealth and vehicle availability can be barriers to non-automobile utilization.

# Definitions and Accessibility Functions

Several studies have helped define accessibility, as well as refine methods for calculating accessibility.

## Accessibility Definitions

Accessibility is defined as the ease with which an individual can reach destinations and/or points-of-interest through existing transportation infrastructure and/or services in terms of either a specific type of transportation mode, or multimodal transportation facilities (Barkley & Gomes-Pereira, 2015; Chandra et al., 2017; Lin et al., 2014; Zuo et al., 2018). This is not to be confused with mobility, which is the ability to move from one place to another (Farber & Grandez Marino, 2017). While the above statement defines accessibility in the broadest sense, there are several other variations of the term commonly found in the literature.

Destination accessibility determines the ease of access to trip attractions using the mix of the land use in the immediate area (Huang et al., 2018). Destination accessibility leads to two other forms of the measure: passive and active.

- Passive accessibility describes how easily people may reach a specified activity location.
- Active accessibility describes how easily a person at a particular location can engage in certain activities available at specific destinations scattered across the geographic space (Cascetta, 2009; Farber & Grandez Marino, 2017).

Additional qualifiers of accessibility include relative and normal accessibility (Fransen et al., 2015), positive accessibility (Paez et al., 2012), and transit accessibility (Manout et al., 2018). Relative accessibility defines the level of access compared to all other areas within a given region. Normative accessibility defines the minimal accessibility a policymaker would expect to have provided for the population of a certain area or region. These two variations of the definition will produce two different outcomes, in which normative will guide interventions to increase access to the minimum threshold identified, while relative is a measure of the current or proposed access compared to other areas. Somewhat related is the notion of positive accessibility which measures the experiences of individuals traveling to engage in 'out-of-home' activities. Transit accessibility analysis, on the other hand, has been used in some cases to track the ease with which residents or workers can reach transit facilities based on temporal or distance factors. These last two definitions (positive accessibility and transit accessibility) differ from those previously mentioned in that they do not account for the traditional travel from one location to another for a specific social or economic purpose.

## Calculating Accessibility

Building from the research presented above, the drive time and fixed route transit-time access metrics for people and business in this project are calculated using one of two functional forms (Figure 5): a decay function or a metric reflecting travel time to the first, or first and second, nearest destinations. The decay function is used for situations in which having access to more than one of a given destination (like a job or an urgent care center) can be beneficial. The nearest destination approaches are used where access to only one or two of a given destination (like a hospital) is sufficient and people are less likely to consider options located further away. Generally, two destinations are preferred as the closest facility may be closed or temporarily inaccessible, and a second destination helps account for resiliency in accessibility metrics.

The destinations selected and the use of a decay function align with the prior ARC *Access in Appalachia* Research, while the analysis of travel time to nearest destinations is similar to the "crisis" destination approach take in the Richmond study.

**Drive and Fixed-Route Transit Access for Peoples**

| Destination | Description | Equation | Definitions |
|---|---|---|---|
| Town Centers<br>Colleges & Universities<br>Mental Health<br>Substance Abuse<br>Urgent Care | Counts of destinations accessible, weighted by a decay function.<br><br>Closer destinations are given more weight. | $A_i = \sum_{j=1}^{n} D_j e^{-\beta t_{ij}}$ | $A_i$ = Access of zone i<br>$D_j$ = Destinations in zone j<br>$\beta$ = Decay parameter<br>$t_{ij}$ = Travel time from zone i to zone j |
| Jobs | Counts of jobs accessible, weighted by a decay function.<br><br>Closer jobs are given more weight. | $A_i = \sum_{j=1}^{n} D_j e^{-\beta t_{ij}}$ | $A_i$ = Access of zone i<br>$D_j$ = Destinations in zone j<br>$\beta$ = Decay parameter<br>$t_{ij}$ = Travel time from zone i to zone j |
| Hospitals | Travel time to the nearest hospital, inverted.<br><br>Better access receives a higher score. | $A_i = 1/t_{ic}$ | $A_i$ = Access of zone i<br>$t_{ic}$ = Travel time from zone i to the closest destination |

**Drive Access for Businesses**

| Destination | Description | Equation | Definitions |
|---|---|---|---|
| Commercial Airport<br>Major Seaport<br>Inland Port<br>Truck-Rail Intermodal Facility<br>Truck-Air Intermodal Facility | Travel time to the nearest destination, inverted, plus travel time to the second-nearest destination, inverted.<br><br>Better access receives a higher score. | $A_i = 1/t_{ic1} + 1/t_{ic2}$ | $A_i$ = Access of zone i<br>$t_{ic1}$ = Travel time from zone i to the closest destination<br>$t_{ic2}$ = Travel time from zone i to the second-closest destination |
| Workforce | Number of people with some college education accessible, weighted by a decay function.<br><br>Closer potential workforce is given more weight. | $A_i = \sum_{j=1}^{n} D_j e^{-\beta t_{ij}}$ | $A_i$ = Access of zone i<br>$D_j$ = Destinations in zone j<br>$\beta$ = Decay parameter<br>$t_{ij}$ = Travel time from zone i to zone j |

**Figure 5. Functional Form of Drive Time and Fixed Route Transit Time Metrics**

The steepness of the decay function is governed by the decay parameter ($\beta$). The parameter was calibrated based on data from the National Household Travel Survey (2017) on trip lengths for states within the ARC footprint. Figure 6 shows that 95 percent of all trips to healthcare and job destinations are seventy-five minutes or less. Education trips and trips for shopping, services, meals, and errands—aggregated to the proxy destination of Town Centers—tend to be somewhat shorter. For ease of comparability across destination metrics, this study calibrated the decay curve for all destinations using the same parameter. The decay parameter ($\beta$) is defined so that if the travel time in the access function is set to the 95th percentile value of 75 minutes, then the weight applied to the destination count ($e^{-\beta t}$) is equal to 0.05.[3] For computational effort, destinations were not considered beyond the 75-minute threshold.

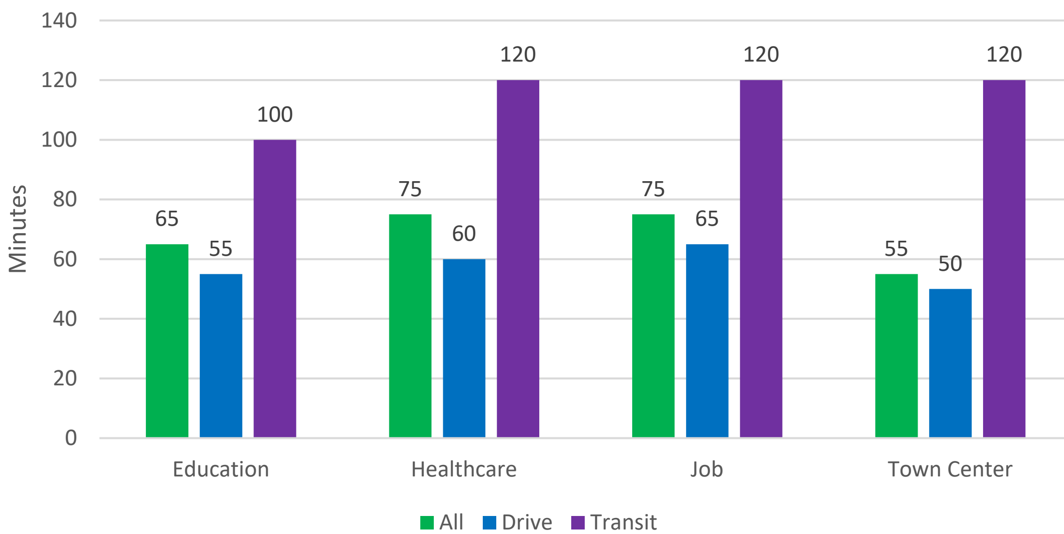


**Figure 6. 95th Percentile Travel Time in ARC States by Mode and Destination Type[4]**

[3] $\beta$ = 0.039943

[4] Source: National Household Travel Survey (2017). Town Center results aggregate shopping, services, meals, and errands.

# 3

# Data Review

## Roadway and Transit Networks

The study team reviewed available roadway and transit networks to determine if travel time calculations would be possible. This included data within North Carolina, as well as for surrounding states (Table 7). Some common trips, such as a medical or work commute trips of an hour for households residing close to the border with another state, could take an individual outside of state boundaries. For freight and logistics trips, longer travel times and destinations outside of state boundaries are even more relevant.

Table 7. Roadway and Transit Network Data

| Layer | Resource | Public Source | Description of Data Available |
|---|---|---|---|
| **General Transit Feed Specification (GTFS) Feeds** | TransitLand | https://www.transit.land/ | TransitLand – All GTFS within 60 miles of NC border |
| | TransitFeeds | https://transitfeeds.com/ | TransitFeeds – All GTFS within 60 miles of NC border |
| **Transit Shapefiles of Routes** | ITRE | https://itre.ncsu.edu/ | ITRE – Shapefiles of all fixed route transit in NC |
| **Transit On-Demand/ Community Transportation Presence by County** | ITRE | https://itre.ncsu.edu/ | ITRE Inventory of transit providers in North Carolina, by transit agency, re-coded by county |
| **North Carolina Roads** | NCDOT | https://connect.ncdot.gov/resources/gis/Pages/GIS-Data-Layers.aspx | Roadways with speed limit and other characteristics |
| **South Carolina Roads** | South Carolina Department of Transportation | http://info2.scdot.org/GISMapping/Pages/GIS.aspx | Roadway with characteristic fields, limited speed data |

| Layer | Resource | Public Source | Description of Data Available |
|---|---|---|---|
| **Virginia Roads** | Virginia Department of Transportation | https://virginiaroads-vdot.opendata.arcgis.com/ | Roadways with speed limit and other characteristics |
| **Georgia Roads** | Georgia Department of Transportation | https://www.dot.ga.gov/GDOT/Pages/RoadTrafficData.aspx | Roadways and speed limits |
| **West Virginia Roads** | West Virginia Department of Transportation | https://data-wvdot.opendata.arcgis.com/ | Roadways and speed limit signs |

Because this study utilizes a 75-minute drive and transit-time analysis for all block groups in North Carolina, other surrounding state's roadways were needed. Dissimilarities across roadway characteristics files and limited data availability of roadway characteristic files, such as roadway locations (e.g., centerlines for state-owned roads), roadway functional classification, posted speed limit, etc., of surrounding states, led the project team to use ESRI's pre-built network for continuity in the analysis between states. This involved ESRI's roadway network and Network Analyst geoprocessing tools for origin-destination (O/D) modeling.[5] ESRI's network was selected for this analysis due to its ready to use format. An additional benefit of using ESRI's network is the inclusion of historic traffic patterns that can improve modeling outcomes with real-world conditions.

Several sources of GTFS data for transit systems were reviewed to check for systems within sixty miles of the North Carolina border. To supplement existing feeds, the study team manually processed schedule data for 31 transit systems to generate GTFS feeds due to lack of – or lack of access to – the respective agency's source GTFS information. This was implemented by geolocating stops for each transit provider and cross-referencing stop times and locations with published schedules for all routes the provider offers. A script was then run to produce the various inputs into GTFS format for the purpose of this analysis. Table 8 presents a list of the transit provider data included in the analysis.

[5] https://www.esri.com/en-us/arcgis/products/arcgis-network-analyst/features

Table 8. Fixed Route and Deviated Fixed Route Transit Providers with GTFS Files Available or Converted for the Purpose of the Pilot Study

| Agency | System Type | Area Served | GTFS Available from Prior Sources | GTFS Files Converted |
|---|---|---|---|---|
| ART (Asheville Rides Transit) | City, Fixed Route | Buncombe | ✓ | |
| Apple Country Public Transit (operated by WNC Source, formerly WCCA) | Single-County | Henderson | | ✓ |
| AppalCART | Combined City/County | Watauga | | ✓ |
| Ashe County Transportation Authority, Inc. | Single-County | Ashe | | ✓ |
| Buncombe County Mountain Mobility (Mountain Mobility Trailblazer Routes) | County | Buncombe | | ✓ |
| Chapel Hill Transit | City | Orange | ✓ | |
| Charlotte Area Transit (CATS) | City | Mecklenburg | ✓ | |
| Cherokee County Transit | Single-County | Cherokee | | ✓ |
| CKRider (Concord Kannapolis Area Transit) | Multiple Municipalities | Cabarrus | ✓ | |
| Davidson County Transportation System | Single-County | Davidson | | ✓ |
| Duke Transit | University Transit System | Durham | ✓ | |
| EBCI Transit (Cherokee Transit) | Tribal Transit System | Qualla Boundary | | ✓ |
| Elkin Circulator-YVEDDI | City | Davie | | ✓ |
| Fayetteville Area Transit System (FAST) | City | Fayetteville | ✓ | |
| Gaston County ACCESS Central Transportation | Single-County | Gaston | | ✓ |
| Goldsboro-Wayne Transportation Authority | Combined City/County | Wayne | | ✓ |
| GoCary | City | Wake | ✓ | |
| GoDurham | City | Durham | ✓ | |
| GoRaleigh (Capital Area Transit) | City | Wake | ✓ | |

| Agency | System Type | Area Served | GTFS Available from Prior Sources | GTFS Files Converted |
|---|---|---|---|---|
| GoTriangle | Regional Express Bus | Triangle Region (Orange, Wake, Durham Counties) | ✓ | |
| Greensboro, City of (GTA, Greensboro Transit Authority) | City | Guilford | ✓ | |
| Greenville, City of (GREAT, Greenville Area Transit) | Single-County | Pitt | | ✓ |
| Haywood Public Transit (operated by Mountain Projects Inc.) | Single-County | Haywood | | ✓ |
| High Point, City of (High Point Transit System) | City | Guilford | ✓ | |
| Iredell County (ICATS) | Single-County | Iredell | | ✓ |
| Jackson County Transit | Single-County | Jackson | | ✓ |
| Jacksonville | City | Onslow | | ✓ |
| Kerr Area Transportation Authority | Multi-County | Franklin, Granville, Vance, Warren | | ✓ |
| Link Transit | Single-County | Alamance | ✓ | |
| Macon County Transit | Single-County | Macon | | ✓ |
| Mocksville Circulator-YVEDDI | City | Davie | | ✓ |
| MyRide Rock Hill | City | York (SC) | | ✓ |
| Ocracoke Island Tram | Single-County | Hyde | N/A (seasonal operations only) | N/A (seasonal operations only) |
| Ocracoke Passenger Ferry | Multi-County | Hyde, Dare | N/A | N/A |
| Orange County Public Transportation | Single-County | Orange | | ✓ |
| Person County (PATS) | Single-County | Person | | ✓ |
| Piedmont Authority for Regional Transportation (PART) | Regional Express Bus | Piedmont Triad Region | ✓ | |
| Raleigh – NCSU | University Transit System | Wake | ✓ | |
| Rockingham County Council on Aging Inc. | Single-County | Rockingham | | ✓ |
| Rocky Mount Tar River Transit (TRT) | Multi-County | Nash, Edgecombe | | ✓ |

| Agency | System Type | Area Served | GTFS Available from Prior Sources | GTFS Files Converted |
|---|---|---|---|---|
| Rutherford County Transit | Single-County | Rutherford | | ✓ |
| Salisbury Transit | City | Rowan | ✓ | |
| Scotland County Area Transit System | Single-County | Scotland | | ✓ |
| Transportation Administration of Cleveland County Inc. | Single-County | Cleveland | | ✓ |
| Transylvania County Transportation | Single-County | Transylvania | | ✓ |
| Wilmington (WAVE Transit) | Combined City/County | New Hanover | ✓ | |
| WPRTA (Greenway Public Transportation)-Morganton Loop Route | Multi-County | Burke | | ✓ |
| WPRTA (Greenway Public Transportation)-Catawba County Flex Routes | Multi-County | Catawba | | ✓ |
| WPRTA (Greenway Public Transportation)-Taylorsville Flex Route | Multi-County | Alexander | | ✓ |
| WSTA (Winston-Salem Transit Authority) | City | Forsyth | ✓ | |

## Demand-Response Transit Providers

Table 9 presents a list of demand-response providers in North Carolina. There are 79 providers in North Carolina that cover 99 out of its 100 counties.[6] Each demand-response provider is sorted into a peer group according to the criteria used in *Geographic and Demographic Methodology for Peer Group Classification of Rural Demand-Responsive Transportation* (Monast et al., 2011). This report provided peer groupings for systems based on geographic and demographic factors that are beyond of the control of the transportation systems (Figure 7).

**Table 9. Demand-Response Transit Providers and their Associated Peer Group**

| Demand-Response Provider | Peer Group |
|---|---|
| Alamance (ACT) | 2 |
| Albemarle Regional Health Services (ICPTA) | 4 |
| Alleghany County | 5 |
| Anson County | 4 |
| AppalCART Boone | 4 |
| Ashe County | 5 |
| Avery Co. (ACT) | 5 |
| Beaufort County Developmental Center, Inc. | 4 |
| Bladen County (BARTS) | 4 |
| Brunswick Transit System, Inc. | 4 |
| Buncombe County | 3 |
| Cabarrus County | 2 |
| Cape Fear Public Transportation Authority (Wave) | 1 |
| Carteret County | 3 |
| Caswell County | 4 |
| Chatham Transit Network | 4 |
| Cherokee County | 5 |
| Choanoke Public Transportation Authority (CPTA) | 4 |
| Clay County | 5 |
| Cleveland County (Transportation Administration of Cleveland County, Inc.) | 3 |
| Columbus County | 4 |
| Craven County (CARTS) | 4 |
| Cumberland County Transit | 2 |
| Dare County | 3 |
| Davidson County | 2 |
| Duplin County | 4 |
| EBCI Transit | 5 |
| Gaston County | 2 |
| Gates County | 4 |

[6] Forsyth County was excluded from the analysis due to data availability limitations.

| Demand-Response Provider | Peer Group |
|---|---|
| Go Durham/Durham County | 1 |
| Go Wake | 1 |
| Goldsboro-Wayne Transportation Authority | 2 |
| Graham County | 5 |
| Greene County | 4 |
| Guilford County | 1 |
| Harnett County | 3 |
| Hoke County | 4 |
| Hyde County / Tyrrell County | 4 |
| Iredell County (ICATS) | 2 |
| Jackson County | 5 |
| Johnston County Area Transit (JCATS) | 3 |
| Kerr Area (KARTS) | 3 |
| Lee County (COLTS) | 2 |
| Lenoir County | 3 |
| Lincoln County | 3 |
| Macon County | 4 |
| Madison County Transportation Authority | 5 |
| Martin County | 4 |
| McDowell County Transportation | 5 |
| Mecklenburg County (MTS) | 1 |
| Mitchell County Transportation Authority | 5 |
| Moore County | 3 |
| Mountain Projects Inc. Haywood Co. | 4 |
| Onslow United Transit System, Inc. (OUTS) | 2 |
| Orange County | 2 |
| Pender Adult Services Inc. (PAS) | 4 |
| Person County (PATS) | 3 |
| Pitt County/Pitt Area Transit System | 2 |
| Polk County | 5 |
| Randolph County (RCATS) | 3 |
| Richmond Interagency Transportation, Inc. | 3 |
| Robeson County (SEATS) | 3 |
| Rockingham (ADTS) | 3 |
| Rowan Transit System (RTS) | 2 |
| Rutherford County Transit | 4 |
| Sampson County | 4 |
| Scotland County (SCATS) | 3 |
| Stanly County (SCUSA) | 3 |
| Swain County Focal Point on Aging Inc. | 5 |
| Tar River Transit | 3 |

| Demand-Response Provider | Peer Group |
|---|---|
| Transylvania County | 5 |
| Union County | 2 |
| Washington County (Riverlight Transit) | 4 |
| Western Carolina Community Action, Inc. (WCCA-Apple Country (Henderson County)) | 2 |
| Western Piedmont Regional Transit Authority | 4 |
| Wilkes Transportation Authority (WTA) | 4 |
| Wilson County | 2 |
| Yadkin Valley Econ Dev Dist (YVEDDI) | 3 |
| Yancey County Transportation | 5 |

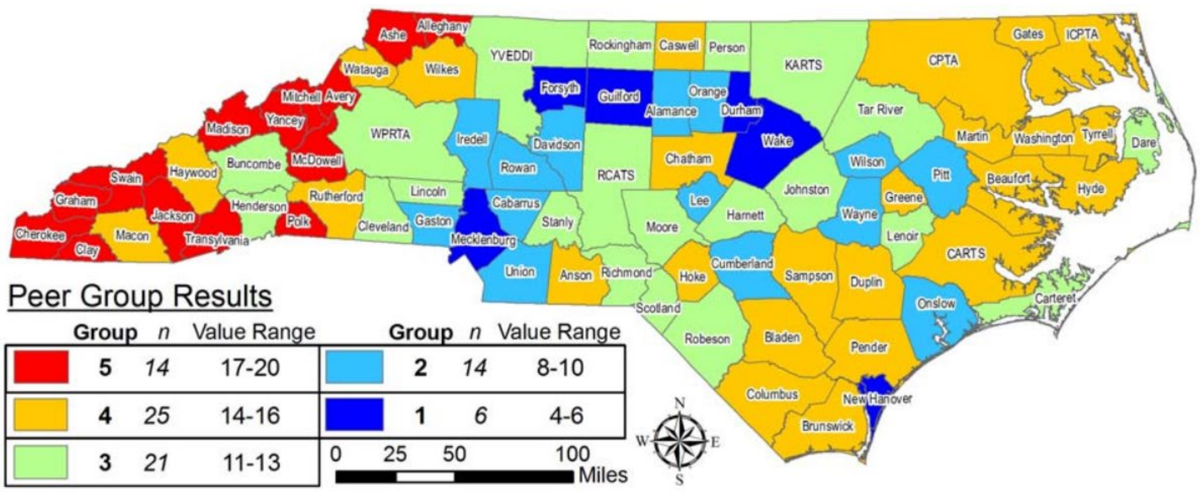


**Figure 7. North Carolina Demand Response Transit Provider Peer Groups (Source: Monast et al., 2010)**

The project team obtained Operational Statistics (OpStats) data for fiscal year 2022. These data provide system summary information for community transit providers in the state receiving federal funding. The project team also developed a survey to obtain trip scheduling practices (e.g., trip scheduling tools and timeliness) and distributed it to community transit service providers in summer 2023. The survey template is provided in *Appendix A-3: Community Survey Template*.

The project team supplemented OpStats and survey data with connectivity data developed as part of the 2017 NCDOT report, *A Methodology for Measuring Urban and Community Transportation Connectivity in North Carolina* (ITRE, 2017).[7] This evaluation determined the level of connectivity for community transit providers by comparing existing connections with transit and rail against expected connections. The more observed connections relative to expected connections that a system provided, the higher connectivity score to destinations outside of the transit operator's service area (Equation 1).

[7] Per ITRE (2017): "Transit systems are expected to connect if their service areas are within 10 miles of other transit systems. Connectivity for Zo and Ze is measured on a binary scale. If two systems connect at least once (time and space), they are assigned a score of 1. Systems that do not connect on both a temporal and spatial dimension are assigned a 0." (p. 17)

$$\frac{\sum Zo}{\sum Ze}$$

(Equation 1)

Where,

$Z_O$ is the sum of the observed transit system connections.

$Z_e$ is the sum of the expected transit system connections.

*Appendix A-2: Definition of a Demand Response Connection* provides more detail on observed and expected transit system connections.

# Pedestrian and Bicycle Infrastructure

Pedestrian and bicycle infrastructure data were obtained from NCDOT's Pedestrian and Bicycle Infrastructure Network (PBIN). This GIS-based resource contains point and linear features representing crosswalks, bike lanes, sidewalks, shared use paths, and other multimodal infrastructure. Because PBIN combines data that are voluntarily supplied by municipalities and actively collected by NCDOT, its data quality and completeness vary throughout the state. However, the research team determined that sidewalk location information from PBIN was sufficient for the *Access in Appalachia* statewide analysis.

# Community Destination Data

Community destinations primarily reflected the guidance in the original *Access in Appalachia* study (ARC, 2020). These destinations include hospitals and trauma centers, urgent care centers (in lieu of primary care centers), mental health and substance addiction centers, colleges and universities, employment opportunities, and town centers. Town centers serve as a proxy variable for a variety of destinations such as banks, post offices, government centers, and other community resources.

## Hospitals and Trauma Centers

Hospital and Trauma Center data were available from the U.S. Department of Homeland Security's Homeland Infrastructure Foundation-Level Data (HIFLD) source.[8] The project team identified hospitals for North Carolina and surrounding states and screened potential locations for open facilities and for general acute care facilities. This filter removed facilities that were not open and other healthcare facilities such as psychiatric, rehabilitation, long term care, military hospitals, and other special care facilities. Hospitals primarily serving only specific patients, such as United States Department of Veterans Affairs (VA) Hospitals and Indian Hospitals were excluded from analysis. A total of 163 hospitals were included as part of this analysis. See Table 10 for a description of hospitals by state and level of care.

[8] https://hifld-geoplatform.opendata.arcgis.com/

### Table 10. Description of Hospitals by State and Level of Care

| Facility Level | North Carolina | South Carolina | Georgia | Virginia | West Virginia | Tennessee |
|---|---|---|---|---|---|---|
| **Level 1** | Capable of providing:<br>• Guidance.<br>• Research.<br>Total care for all aspects of injury (prevention to rehab) | Serves large cities/population dense areas.<br>Should be the lead hospital for a system.<br>Manages large numbers of severely injured patients. | Capable of providing total care for all aspects of injury.<br>Provides leadership in prevention and public educations.<br>Operates organized teaching and research. | Provides total care for every aspect of injury and has adequate depth resources and personnel capable of providing leadership, education, and system planning. | Provides:<br>• Leadership and total care for every aspect of injury.<br>• Research and prevention programs.<br>Mostly university-based teaching hospitals. | Sufficient infrastructure and support to ensure adequate provision of care.<br>Teaching facilities must also meet the requirements of the Residency Review Committee. |
| **Level 2** | Provides trauma care regardless of severity of injury but may lack comprehensive care of Level I center. | Less population-dense areas.<br>Serves as lead facility for areas far away from Level I.<br>Common in rural areas. | Can initiate definitive care for all injured patients but may transfer some to a Level I center.<br>May refer tertiary surgery to Level I Center. | Provides initial definitive care regardless of the severity of injury.<br>Specialty requirements may be fulfilled by on call staff. | Provides initial definitive trauma care; can be academic or a public/private community facility.<br>Research and prevention programs not required. | (See Level 1) |
| **Level 3** | Provides assessment, resuscitation, emergency operations, etc. Arranges for transfer to Level I or II center as needed. | Capable of managing most injuries initially<br>Transfer agreements with Level I or II centers. | Provides:<br>• Surgery and intensive care.<br>• Stabilization of injured patients in emergency operations.<br>• Provides 24-hour coverage.<br>Transfers patients to Level I and II centers. | Provides:<br>• Prompt assessment<br>• Resuscitation<br>• Stabilization<br>• Emergency operations<br>Can transfer patients to higher level centers. Responsible for education and leadership in region. | Serves communities that do not have immediate access to higher levels.<br>Provides:<br>• Prompt assessment.<br>• Resuscitation.<br>• Emergency operation.<br>Stabilization, and arranging for possible transfers. | Center may admit injured patients to individual surgeons but must allow trauma director to have oversight authority for the care of patients. There shall be a method to identify injured patients, monitor the provision of service, and make rounds. |

| Facility Level | North Carolina | South Carolina | Georgia | Virginia | West Virginia | Tennessee |
|---|---|---|---|---|---|---|
| **Level 4** | - | Mostly in rural locations.<br>Usually supplementing care in a larger system. | Provides:<br>• Advance trauma life support before transfer.<br>Surgery and critical care services. | - | Provides advanced trauma life support prior to patient transfer in remote areas.<br>Typically serves as the primary care provider)<br>Usually, small rural hospital emergency departments | - |
| **Level 5** | - | - | Provides:<br>• Initial evaluation<br>• Stabilization<br>• Diagnostic testing<br>• Surgery and care services<br>Prepares patients for higher care levels. | - | - | - |

## Urgent Care Facilities

Urgent Care Facilities data were available from the HIFLD source, and a total of 390 urgent care facilities were used in this analysis. Primary care facilities were not included due to a lack of reliable location information. Additional data limitations are discussed in the *Future Data* Needs chapter.

## Mental Health and Addiction Treatment Centers

Mental Health and Addiction Treatment center data were available for North Carolina and surrounding states from the U.S. Department of Health and Human Service's Substance Abuse and Mental Health Services Administration (SAMHSA). SAMHSA provides a search function to locate facilities filtered by service type and produces a detailed report of the facility, services offered, populations served, and treatment approaches. The study team dataset included both substance abuse and mental health service facilities.

## Colleges and Universities

Colleges and universities, including both two-year and four-year schools, were available from the HIFLD source. The project team only included colleges, universities, professional schools, and junior colleges; other technical and trade schools, cosmetology and barber schools, educational support services, business and secretarial schools, and other specialty schools were excluded. This resulted in 136 colleges and universities within North Carolina and 282 within a 60-mile buffer of North Carolina.

## Town Centers

North Carolina and surrounding states' town centers were created using the United States Census Bureau's "Places" designation data.[9] The project team generated a geographic centroid for each Place polygon. The project team used Census data in lieu of North Carolina-specific datasets to obtain locations for all surrounding states as well.

Utilization of geographic centroids as a proxy for town centers does pose analytical challenges. Because true downtown centers were not a readily available data source for North Carolina nor any surrounding state in the study area, a proxy variable was chosen. The geographic center of a municipality is not necessarily the same as the location of the central business district (CBD); the project team did not have access to CBD locations, although future data enhancements could consider developing an inventory of CBDs throughout North Carolina, possibly leading to skewed results in accessibility for this metric. The accessibility skew will be less for municipalities with a smaller area compared to those with a larger footprint.

[9] https://www2.census.gov/geo/pdfs/reference/GARM/Ch9GARM.pdf

## Demographic Characteristics

Demographic data were obtained from the 2020 ACS 5-year estimates. Data were collected at the Census block group level, the smallest unit of analysis that contains the relevant data profiles. These demographic factors include:

- Zero Vehicle Households (Table B25044),
- Low Income Population (Table C17002),
- Residents with Mobility Impairments over the age of 18 (Table C21007),
- Youth aged 15 and under (Table B23025),
- Seniors aged 65 and over (Table B01001),
- BIPOC Population (Tables B02001, B03002, and B03002),
- Limited English Proficiency (LEP; Table B16002), and
- Level of Education (Table B15003).

The level of education variable was used to identify a labor pool for the business accessibility metric. Those who would be considered as being a priority for businesses are those with at least some level of education beyond high school. The labor pool is therefore identified as those with some college, less than one year, through those who hold a doctorate degree.

Analysis of demographic characteristics is done for each block group. For all demographic characteristics, except for level of education for business access, 2020 block group geography was used. For level of education used for the labor pool in the business access, 2019 block group geography was used. This was due to the timing of the study where block group geographies were changing based on the most recent available data from the Census Bureau.

## Employment

Employment data for Census geographies is available at the Census tract level from the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) 2019 dataset. This data includes the total number of jobs per Census tract and breaks the jobs down by worker age, earnings, NAICS code, race, ethnicity, education, and sex.

The project team also reviewed Data Axle[10] as a potential data source. However, the project team noted workplace location issues, where the location might be tagged to the mailing address rather than the physical location. In addition, employers with multiple sites might have all of their employment numbers reported at the central location, rather than dispersed by specific job site. Furthermore, an InfoUSA subscription is required to download the data. Since specific workplace locations were not required to perform the analysis, the project team only used LEHD data to support accessibility metrics.

[10] https://www.arc.gov/about-the-appalachian-regional-commission/

## Freight Facilities

Key Freight destinations were collected for locations in North Carolina, Georgia, South Carolina, Tennessee, Virginia, and West Virginia, as summarized in Table 11. Based on feedback collected from stakeholders, the project team grouped these datasets based on specific intermodal access:

- Commercial airports (excluding General Aviation airports)
- Seaports (excluding Inland Ports)
- All other intermodal facilities (including air-to-truck, rail-to-truck, and Inland Ports that represent major containerized rail-to-truck facilities)

Table 11. Freight Destinations by Data Source

| Layer | Source | Source Sites | Notes |
|---|---|---|---|
| Air to Truck Intermodal Freight Facilities | Bureau of Transportation Statistics (BTS) | Air to Truck Intermodal Freight Facilities | The Carolina Connector (CCX) was appended to Air to Truck Intermodal Freight Facilities. |
| Rail to Truck Intermodal Freight Facilities | Bureau of Transportation Statistics (BTS) | Rail to Truck Intermodal Freight Facilities | |
| Ports | Bureau of Transportation Statistics (BTS) | Major Ports | |
| Inland Ports (*Grouped with Intermodal Freight Facilities) | Web research | Miscellaneous | The following Inland Ports were manually coded:<br>• GA – Appalachian Port, Bainbridge Port[11], Northeast Georgia Inland Port[12]<br>• NC – Inland Charlotte Port<br>• SC – Inland Port Greer, Inland Port Dillon<br>• VA – Virginia Inland Port<br>• WV – Huntington Port |
| Commercial Airports | Bureau of Transportation Statistics (BTS)<br><br>Federal Aviation Administration (FAA) | Airports<br><br>Airport Data and Information Portal | |
| General Aviation Airports | Bureau of Transportation Statistics (BTS)<br><br>Federal Aviation Administration (FAA) | Airports<br><br>Airport Data and Information Portal | General Aviation Airports were excluded from the *Access in Appalachia* Pilot Study analysis |

# Equity and Transportation Disadvantaged Populations

Equity is a broader concept that goes beyond the transportation disadvantage factors represented by socio-demographic characteristics, and there are a variety of equity types and accepted definitions. Definitions from the Urban Sustainability Directors Network (USDN) include (2014):

[11] Bainbridge is a transload bulk facility.

[12] Expected to be operational in 2026.

- **Distributional equity**—fair distributions of benefits and burdens across all segments of a community, prioritizing those with highest need, as a result of programs and policies.
- **Procedural equity**—inclusive, accessible, authentic engagement and representation in processes to develop or implement programs and policies.
- **Structural equity**—decision-makers institutionalize accountability; decisions are made with a recognition of the historical, cultural, and institutional dynamics and structures that have routinely advantaged privileged groups in society and resulted in chronic, cumulative disadvantage for subordinated groups.

While distributional equity is typically easier to see and measure in terms of outcomes of public investment and community and population characteristics, other types of equity may be considered. Another recent research project developed the following definition of equity for use by NCDOT in transportation planning and STI Prioritization (Huntsinger, 2022):

> *"Equity is improving quality of life by addressing transportation benefits and burdens in a sustainable way. Equitable planning and investment decisions are made through inclusive collaboration to provide safe, reliable, and attainable transportation options. In order to meet the mobility needs of all North Carolinians, it is essential to recognize and mitigate barriers to access experienced by historically underserved communities."*

Accessibility metrics based on travel time calculations in combination with one or several measures of transportation disadvantage can be a building block for reviewing distributional equity as part of transportation planning and project prioritization in North Carolina. Other aspects of equity in transportation planning and project programming processes, such as structural and procedural equity, are important but outside of the scope of the current pilot project and would require follow-up research to evaluate.

The research team reviewed NCDOT's *ITRE Accessing Measures of Transportation Disadvantage for Public Transportation Project Prioritization (*2019) for demographic parameters to be considered as part of equity and transportation disadvantage indicators in the pilot study. As a follow-up to the *Assessing Measure of Transportation Disadvantage for Public Transportation Project Prioritization* research, NCDOT Integrated Mobility Division (IMD) created two screening tools which are publicly available as an online interactive map with the ability to download data for different geography levels:

- Environmental Justice (EJ) Tool
- Transportation Disadvantage Index (TDI; Figure 8)

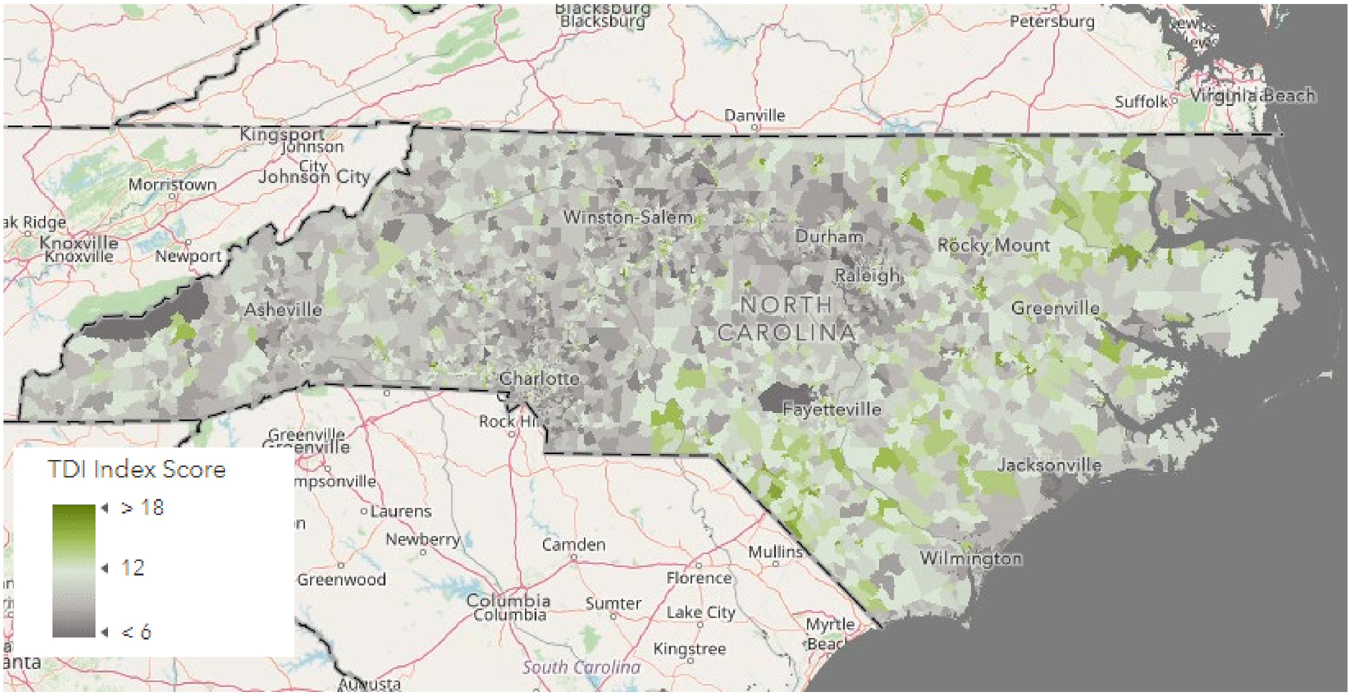


Figure 8. TDI Index Score, Statewide Results (NCDOT, n.d.)

The EJ Tool focuses on low-income, as well as racial and ethnic minority populations; the TDI Tool expands the focus to race, income, personal vehicle access, people with mobility impairments, the elderly and youth, and LEP. TDI compares relative levels of potentially transportation disadvantaged population groups to the region, county, and statewide averages.[13]

The following transportation disadvantage data layers are available at a block group level from the American Community Survey (2016-2020, 5-year average) via the TDI Tool and could be readily used as part of the Access in Appalachia Pilot Study.

- Population age 15 and under
- Population age 65 and over
- People in poverty below 150% of poverty line
- Zero-vehicle households
- Adult population with a disability
- BIPOC population
- LEP households

# County Distress Rankings

Like measures of equity and transportation disadvantage for people, this research also used information on disadvantage for business. The North Carolina Department of Commerce maintains a County Distress

[13] NCDOT, Equity and Transportation Disadvantage Screening Tool. Retrieved from https://storymaps.arcgis.com/stories/7e3bbd00fe014a77b5f1620334209712

Ranking, which scores all 100 counties and places them within three tiers, with Tier 1 counties having greater economic distress (Figure 9). The tiers are based on four factors:

1. Average unemployment rate,
2. Median household income,
3. Percentage growth in population, and
4. Adjusted property tax base per capita.

The intent is to incorporate the rankings into programs and policies that encourage economic activity in less prosperous areas of the state.

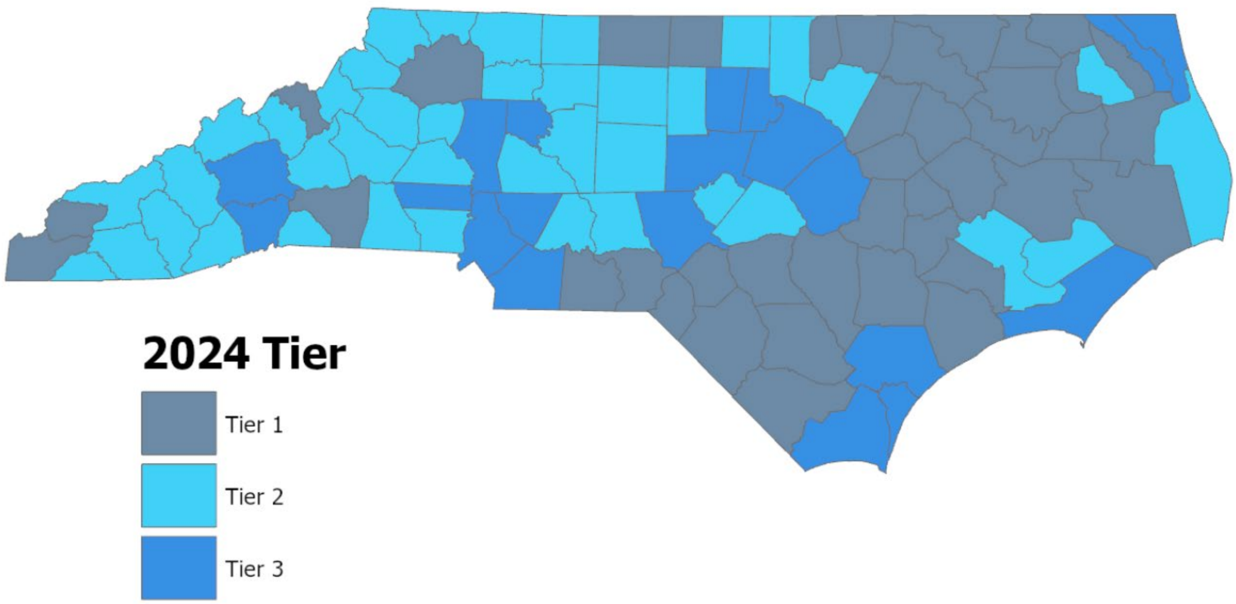


Figure 9. 2024 County Distress Tiers (Source: North Carolina Department of Commerce)

# 4

# Data Analysis

The Access in Appalachia Pilot research surveyed existing access in North Carolina to key household and business destinations. This research viewed **access** through the lens of personal or business access to education, employment, healthcare (including mental health facilities, substance abuse centers, hospitals, and urgent care offices), town centers, intermodal freight facilities, commercial seaports and airports, and labor pools. This research considered statewide access – including access to destinations outside of North Carolina – for the following five modal categories:

### Access for People

1. Personal driving
2. Fixed route transit
3. Demand response transit
4. Cycling and pedestrian travel

### Access for Business

5. Business drive access

Furthermore, for each mode, the research team identified locations in the state where access is limited such that transportation disadvantaged populations (*Equity and Transportation Disadvantaged Populations and County Distress Rankings*) potentially need additional support in accessing destinations and amenities. This is referred to as **opportunity** in this report. For each mode, the research team developed a map that highlights areas of opportunity in the state to enhance access; these are based on a deficit of access for that mode relative to a population that might be greatly helped by greater access by that mode (i.e., need).

The following sections outline the analysis methods, data procedures, and assumptions used by the project team to assess access for each of the five modes.

## Drive Time Analysis

The drive time analysis procedure involved a multi-step approach consisting of destination compilation, developing the drive time model, and post analysis data processing.

## Destination Compilation

Destinations consisted of four household destinations. These include:

1. Town centers (geographic centroid of each municipality),
2. Employment opportunities (jobs; employment-weighted centroid for each block group),
3. Colleges and universities, and
4. Healthcare centers (hospitals, urgent care facilities, mental health centers, and substance abuse treatment centers).

The project team compiled and imported destinations into GIS as individual layers and assigned unique identifiers to each destination location. After assigning unique identifiers, the research team compiled layers into a comprehensive household destinations layer for use in the model.

## Drive Time Modeling

The drive time model used ESRI's proprietary roadway network. The prebuilt roadway network includes information related to the drive time analysis including the full street network, roadway restrictions, and posted speed limit. The research team used population-weighted centroids as points of origins with the applicable Federal Information Processing Standards (FIPS) code for identification in post processing. The drive time analysis used a 75-minute travel time cutoff for analysis. The output is a linear GIS layer connecting the origin points to all possible destinations accessible during the 75-minute travel period. The output table includes the O/D pair (origin block group ID – destination ID), destination rank (the order in travel time to each destination), and the total travel time.

## Accessibility Scoring

The goal of this analysis was to calculate block group O/D combination drive time scores in North Carolina. These scores can be summarized by origin block group, county, and the state. The analysis begins with importing five datasets:

1. North Carolina O/D Census block group drive time combinations (12.6 million rows)
2. North Carolina ACS block group demographics (7,112 rows)
3. North Carolina county names and FIPS codes (100 rows)
4. North Carolina Census block group population (7,112 rows)
5. North Carolina Census block group job counts (9,126 rows, includes block groups outside of NC)

Data cleaning involved reviewing that variables were coded correctly (categorical versus numeric) so that the O/D drive time combo dataset could be properly joined with the block group job counts, block group population, and county names datasets.

Within the O/D drive time combo dataset, there is a data field that communicates the type of amenity present at the destination block group, such as hospital, town center, or university. There is also a data field which communicates the number of minutes required to drive from the origin block group to the destination block group for each combination. For hospitals, the accessibility score is simply the inverse of travel time (so that better access is related to lower travel times). For the remainder of the destinations, access is calculated using a decay function. This requires a new "weighted" field to be appended to the dataset. For example, the weighted employment field is equal to the number of jobs present in the block group. For all other amenities, the weight is equal to one. Once the weighted field is calculated, the following formula is applied to calculate drive time scores (Equation 2):

$$Score = w * exp\ (-\beta * Time)$$

(Equation 2)

Where,

$w$ = weight,

$\beta$ = 0.039943,

$exp$ = Euler's number *e*, and

$Time$ = driving time.

For example, the employment score of block group 371830501002, in downtown Raleigh, to block group 371830535122, along Weston Parkway in Cary, is approximately 2,937.4. The weight (w) is calculated based on the jobs within the destination block group (7,181) and driving time to the destination block group (21 min and 58 sec) away from the block group in downtown Raleigh. Using the above formula, the employment score between these two block groups is: $2{,}973.4\ =\ 7{,}181\ \cdot e^{\ (-0039943 \cdot 21.97)}$.

Figure 5 provides a summary of the accessibility calculations for both hospital and non-hospital destinations. Figure 10 illustrates how the Healthcare Score is calculated.

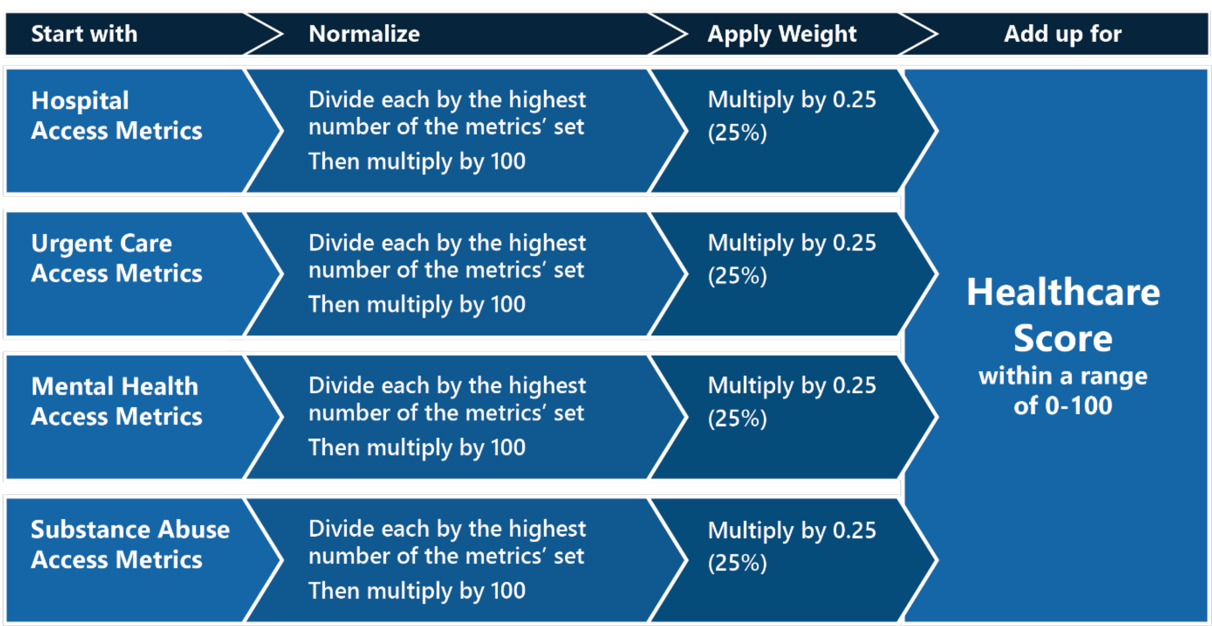


Figure 10. Graphic Illustration of Healthcare Scoring

## Level of Access

Level of access is determined by combining the scores for all four destination type components and weighting them to produce a Drive Time score. As Figure 11 illustrates, scores are relative to the highest overall Drive Time score in North Carolina. However, these scores represent total numbers of accessible destinations and amenities, and these are further discussed in the *Driving and Non-Driving Accessibility in North Carolina* chapter.

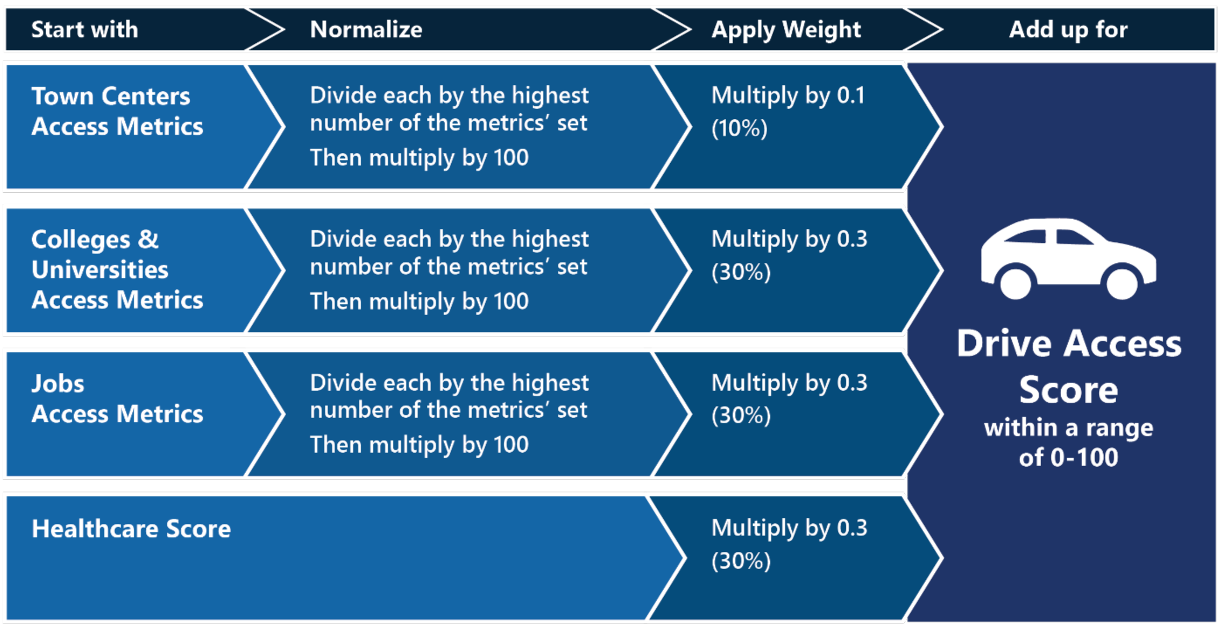


Figure 11. Graphic Illustration of Drive Time Scoring

### Level of Access Map

Figure 12 illustrates the statewide Drive Time accessibility scores. Block groups are combined into quintiles (i.e., each color represents one-fifth of all block groups) with the lowest accessibility scores in pale blue and the highest scores in dark blue across all subsequent accessibility maps.

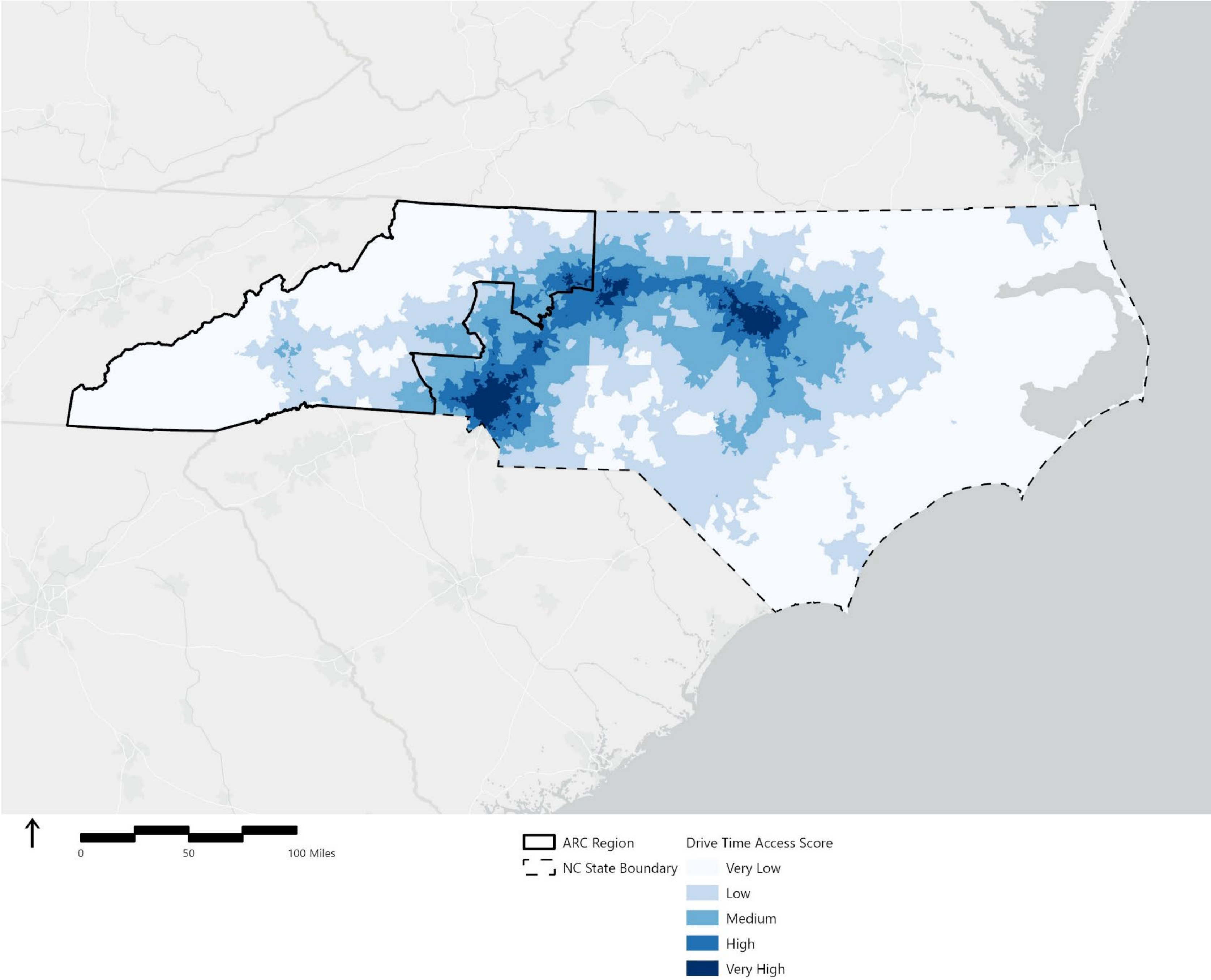


Figure 12. Statewide Drive Time Access Calculations

## Discussion of Results

Based on the drive time analysis, the highest levels of access in North Carolina are along its interstate corridors. This is particularly true for the I-40/I-85 corridor that stretches from Charlotte to Raleigh, where the highest levels of accessibility are located. The large population and employment centers along these high-volume, high-speed corridors allow residents to reach a variety of destinations within the 75-minute commute period. The I-95, I-26, and US-74 corridors provide additional access to destinations particularly around Asheville, Lumberton, Fayetteville, and Rocky Mount.

Suburban block groups of the state's largest cities have moderate levels of access. Their proximity to large employment hubs and destinations contribute to their higher scores, however, the time to travel to these destinations hinders their access score. Even rural block groups along these arterial corridors have moderate levels of access compared to statewide averages of access.

Rural block groups outside of the I-40/I-85 and I-95 corridor (between Fayetteville and Rocky Mount) have the least amount of access in North Carolina. These block groups cluster in the central Piedmont near I-74, the coastal plains, and the hills of the Appalachian Mountains. The agrarian nature of the central Piedmont and coast contributes to the lack of access to destinations with large swathes of land dedicated to farming, raising of animals, and forests. The terrain of the Appalachian Region limits connectivity of rural communities to one another, demanding the need to drive further to reach essential services and destinations.

# Level of Opportunity

Locations of highest opportunity for increased access to destinations in North Carolina are primarily correlated with those who presently lack access. Opportunity in this research equates to the access deficit that a block group, with special consideration for transportation disadvantaged populations and vehicle limited households where applicable. Scores are then renormalized so that the highest opportunity score in the state is equal to 100. Figure 13 provides a graphical illustration of the opportunity calculation for all personal access modes. Drive time access is based on access deficit, as well as access deficit multiplied by TDI.

As seen in Figure 14, the mountains block groups of Appalachia, coastal plains, and central Piedmont have the highest opportunities for driving access improvements.

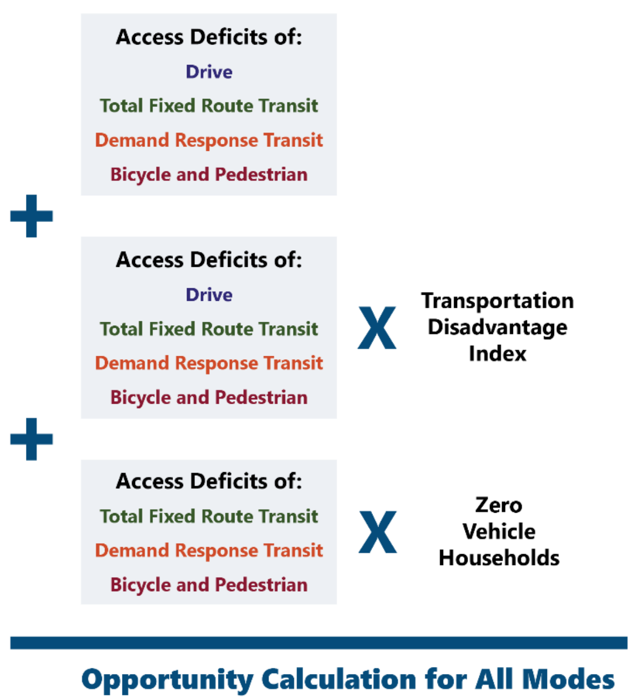


**Figure 13. Opportunity Calculation for All Modes**

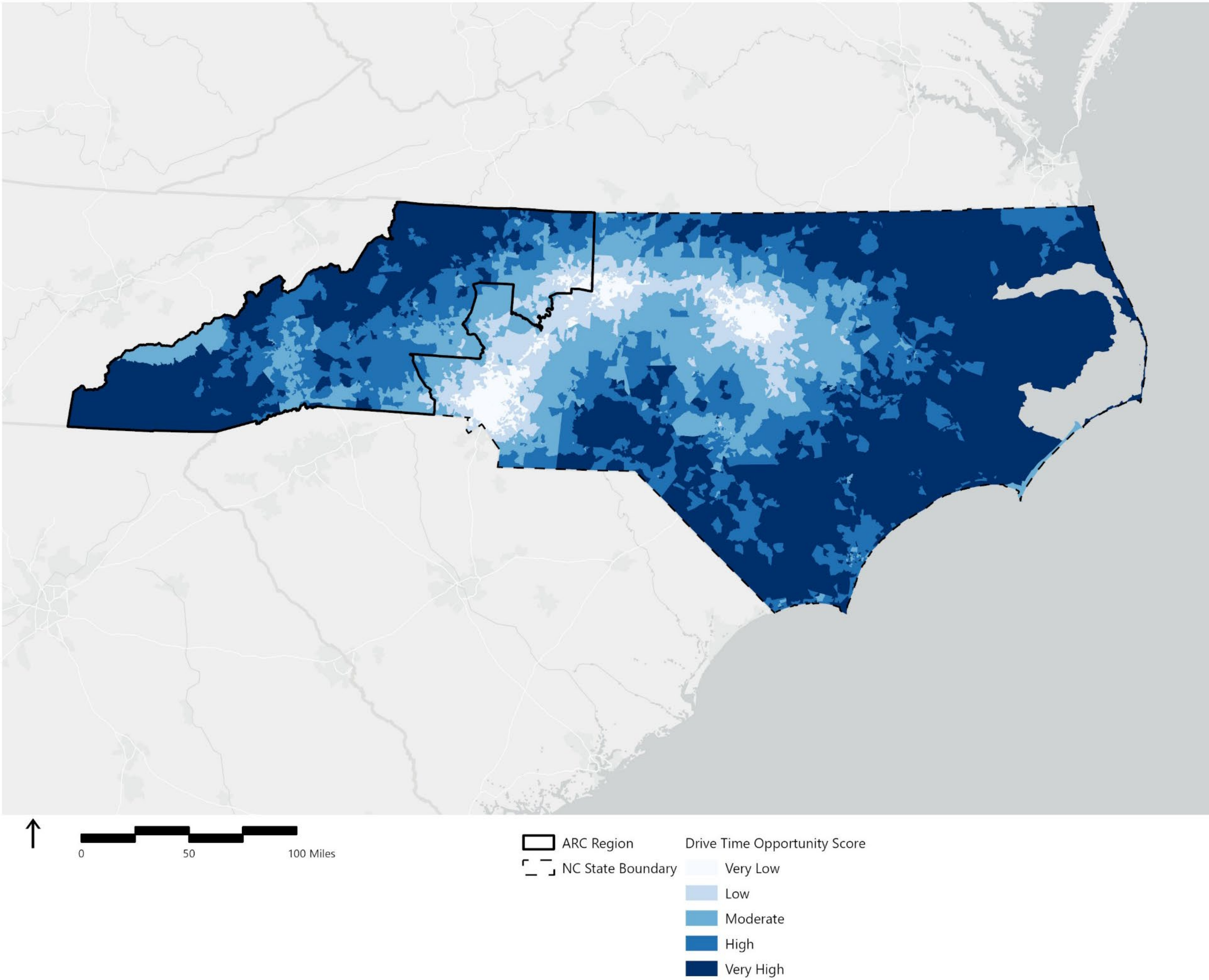


Figure 14. Statewide Drive Time Opportunity Calculations

The Appalachian Region of the state has high opportunity for projects that improve drive time access based on its lack of connections and limited road system due to topography challenges. Coupled with large pockets of higher transportation disadvantaged block groups, this area receives high opportunity scores compared to other block groups in the state.

The central Piedmont has its highest opportunity block groups around the I-74 corridor south of US-64 and US-421. The lack of higher order functional classification roadways in this area limits residents' ability to travel, particularly east-west throughout the central Piedmont.

The coastal region of the state has the highest continuous concentration of high opportunity block groups. High transportation disadvantaged populations coupled with relatively few dense urban centers and higher order functional classification roadways makes it difficult for residents to quickly access daily destinations in this region.

# Fixed Route Transit Analysis

The fixed route transit analysis involved a multi-step process of destination procurement, compilation of transit providers, building and running of transit models, and post analysis data processing.

## Destination Compilation

Fixed route transit analysis destinations consisted of the same four household destination types as the Drive Time analysis:

1. Town centers (geographic centroid of each municipality),
2. Employment opportunities (jobs; employment weighted centroid for each block group),
3. Colleges and universities, and
4. Healthcare centers (hospitals, urgent care facilities, mental health centers, and substance abuse treatment centers).

This analysis used a similar pre-analysis data process as the Drive Time analysis using unique identifiers.

## Transit Provider Compilation

Several sources of GTFS data feeds for transit systems were reviewed to check for systems within sixty miles of the North Carolina border. The research team used this buffer for any potential trips that could be made between transit providers. Only one such case was found between Rock Hill My Ride (South Carolina) and the Charlotte Area Transit System (CATS). Therefore, the research team did not use any other transit providers outside of North Carolina in this analysis.

Transit providers are organized into two categories for the purpose of this analysis: ready-to-use GTFS and GTFS outstanding networks. For those categorized as ready-to-use GTFS networks, the systems were brought into GTFS using the most recent schedule between May and June 2022. The research team transformed GTFS stops and GTFS shapes to features to visualize the transit network in GIS. For those categorized as GTFS outstanding networks, additional data processing was required.

The project team compiled pdf or online schedules and maps for each transit provider that did not have a readily available GTFS. These schedules and stop locations were compiled into a Microsoft Excel workbook, where each sheet has a unique route, direction, and day type (ex. Rt 1 Weekdays EAST and Rt 1 Weekdays WEST would require two separate sheets). Schedules and stops were referenced and populated into the Excel workbook utilizing the GTFS template rules discussed in *Appendix A-5: GTFS Template*.

The research team could then run the Excel schedule files with the GTFS generator script and app. The GTFS generator is an R script that has been turned into a simple Shiny App. The input of the script/app is three files: a schedule template in the form of an Excel workbook (each sheet containing the timetable for a particular route), a stops shapefile, and a routes shapefile. The R script computes each of the three input files included in a GTFS zip folder, then zips all files together in a new folder.

## Transit Modeling

Fixed route transit modeling consisted of three steps, 1) building the network, 2) choosing an optimal start time, and 3) the O/D analysis.

### Building the Network

Once all GTFS datasets have been compiled and cleaned, the research team imported them into a transit model in GIS. Due to several transit providers overlapping in their respective service areas, a series of models were used to account for potential transfers between providers. These transit models consisted of the following regions and transit providers:

- **Asheville Metro Region**
    - Asheville Redefines Transit, Apple Country Transit, Buncombe County Transit
- **Charlotte Metro Region**
    - CATS, CKRider, Rock Hill MyRide, ICATS, Gaston County Access[14], Gastonia Transit
- **Triangle/Triad Metro Region**
    - Capital Area Transit, Chapel Hill Transit, DC Rides, Duke Transit, GoCary, GoDurham, GoTriangle, Greensboro Transit, High Point Transit, LINK, NCSU Transit, Orange County Transit, PART, WSTA
- **Non-regional Systems**
    - ACTA, AppalCART, CARTS, Cherokee County Transit, EBCI, FAST, GWTA, GREAT, Greenway Transit, GWTA, Haywood County Transit, Jackson County Transit, Jacksonville Transit, KARTS, Macon County Transit, Moore County Transportation Services, PATS, Rutherford County Transit, Salisbury Transit, SCATS, SKAT, Tar River Transit, Transportation Authority of Cleveland County, WAVE, Wilkes Transportation Authority, YVEDDI

Once the transit providers were allocated to their respective model regions, the research team imported them into the GTFS to Public Transit Data Model Tool in GIS. This tool converts one or more GTFS public transit datasets to a set of feature classes and tables that represent the transit stops, lines, and schedules

[14] Gastonia Transit plans a transition to a microtransit system in July 2024 and will no longer operate fixed routes; the transit data analysis was based on summer 2022 route data

in the format defined by the Network Analyst public transit data model.[15] This tool takes all input GTFS datasets and combines them into the same set of output tables and feature classes, which allows Network Analyst to model the agencies together. The outputs of this tool include the following (Figure 15):

- Stops
- LineVariantElements
- Calendars
- CalendarExceptions
- Lines
- LineVariants
- Runs
- ScheduleElements
- Schedules


Figure 15. Built Transit Network for Charlotte Metro Area

[15] https://pro.arcgis.com/en/pro-app/2.9/tool-reference/public-transit/gtfs-to-public-transit-data-model.htm

*Pedestrian Networks*

After creating the complete transit model, a street network is needed to model first and last mile travel. A complete street network is created with two required fields: Restrict Pedestrians and Road Class. The Restrict Pedestrians field is a binary field that tells the model where pedestrians can and cannot walk along the roadway. An example of this is pedestrians cannot walk along an access-controlled roadway, such as an interstate, but could walk along Main Street through a downtown commercial corridor. For this study, the research team used TIGER centerlines from the U.S. Census Bureau and used the following roadway classifications to restrict pedestrians from walking along the modeled roads: FTFCC code S1100 (Primary Road) and S1630 (Ramp). Due to a lack of comprehensive sidewalk data and that pedestrians will likely still walk along a roadway without a sidewalk, the presence of a sidewalk along a roadway was not considered in first/last mile calculations. Road Class is an optional field required by Network Analyst that indicates the type of road and is used in the network dataset for configuring walking directions.[16] For this study, the research team assumed that pedestrians could walk in any direction and the field is kept null.

For pedestrians to utilize the street network from the transit network, the two must be joined together in the model. This was done using the Connect Public Transit Data Model to Streets tool. This tool snaps a copy of the transit stops to the streets and generates a straight line connecting each stop's original location with the location where it snapped to the street. The connectors are used in the network dataset to model travel between the streets and transit lines.[17] Transit stops will only be connected to streets where the *RestrictPedestrians* parameter is not present.

The research team built the transit network dataset after transit stops were connected to the street network. This was done using the Create Network Dataset from Template tool, utilizing ESRI's Transit Network Template. This created the transit network dataset used for the analysis. Within the newly built dataset, the research team adjusted group connectivity for the street edges. Within the template, it is automatically set to 'endpoint,' where modeled users can only enter and exit the roadway segment via the start and stop points of the line. This analysis required the policy changed from 'endpoint' to 'any vertex,' allowing the modeled pedestrians to utilize the roadway at any point. All other policies and restrictions were left to the default setting within ESRI's template. The research team then built the network using the Build Network tool.

## Choosing the Optimal Start Time

After initial inspection of the dataset and consideration of when transit users are most likely to utilize transit in a consistent manner, the research team selected the morning peak period (7am – 9am) as the starting analysis point. As fixed route transit is on a fixed time schedule, the time when a person leaves the house has a significant impact on how far they will be able to travel within their standard commute time. For example, if a transit rider leaves one minute late from their house, they may miss their bus, thus significantly reducing their potential transit travelshed. To account for this, transit travelsheds were performed during the morning peak period to identify when each regional model should start.

The transit travelshed for each model area considered each population weighted centroid for every block group within the model area. The model area includes the full county for which a fixed route transit line is present. Using the Service Area tool in the ESRI Network Analysis toolbox, the research team imported population weighted centroids of block groups as the "facilities" (i.e., origins) from which our service area

[16] https://pro.arcgis.com/en/pro-app/latest/help/analysis/networks/create-and-use-a-network-dataset-with-public-transit-data.htm.

[17] https://pro.arcgis.com/en/pro-app/latest/help/analysis/networks/create-and-use-a-network-dataset-with-public-transit-data.htm.

will originate. The parameters for the analysis included setting the mode to public transit time, the direction as away from origin facilities, and the maximum travel time threshold as 75 minutes. The output geometry is set to standard precision with GIS polygons able to easily identify the full extent of the fixed route transit travelshed. To identify the optimal start time for the full analysis, the starting time was changed in five-minute increments starting at 7:00 am and continuing to 9:30 am. The start time with the largest transit travelshed was chosen as the optimal starting time for the entire network model. This process was repeated for each of the three other regional models.

The following start times were chosen as a result of this analysis:

1. **Asheville Regional Model:** 7:25 am
2. **Charlotte Regional Model:** 8:50 am
3. **Triangle/Triad Regional Model:** 7:40 am
4. **Nonregional Model:** 8:40 am

### Origin-Destination Analysis

With the starting time chosen, the research team applied the accessibility model using the O/D cost matrix tool in ESRI's Network Analyst. This tool finds and measures the least-cost paths along the network from origins to destinations,[18] akin to what a person traveling from their point of origin to their destination would likely do. Like the Drive Time analysis, this process required the population weighted block group centroids to be imported as points of origins with the block group FIPS code used for identification in post processing. Destinations were also imported with their unique IDs, allowing for post processing analysis of accessible destinations. Additional parameters set included the start time of the analysis and the 75-minute transit travel time threshold. The analysis is then applied for each regional transit model. The output is a linear GIS layer connecting the origins to all possible destinations accessible during the 75-minute transit travel period. The output table includes the O/D pair (origin block group ID – destination ID), destination rank (the order in travel time to each destination), and the total public transit time.

The same procedure was done for the nearest hospital analysis. Population weighted centroids were imported as points of origins and hospitals were imported as destinations, with their respective IDs brought in as well for post-processing identification. All other criteria remained the same in the analysis except for the 75-minute travel time parameter; this was removed. This allowed the research team to identify the closest hospital, regardless of transit travel time. This was done as the research team assumed individuals would be less sensitive to extended travel times due to the vital medical services delivered by hospitals.

## Accessibility Scoring

As part of accessibility scoring, the project team removed duplicate O/D pairs as a result of the fixed route transit modeling. This was done to provide a more accurate estimate of accessibility. Like the Drive Time analysis, a weighting field assigns a weight of 1 to all destinations except for employment block group centroids. Employment centroids are assigned a weight equal to the number of jobs present in the block group. Additional fields for scores are added for each household destination type (town centers,

[18] Network Analyst solvers—ArcGIS Pro | Documentation

colleges/universities, mental health facilities, substance abuse centers, urgent care facilities, and employment). The nearest hospital analysis is conducted in a separate manner as simply the inverse of travel time (see Figure 5). For all other destinations, the research team generated a fixed route access score according to (Equation 3).

$$Fixed\ Route\ Transit\ Access\ Score = destination\ weight * e^{-0.039943*transit\ time}$$

(Equation 3)

Where,

$destination\ weight$ = the weight associated with each destination type.

$transit\ time$ = the fixed route transit time calculated in the model.

Equation 3 is derived from the right-hand portion of the active accessibility function of $A_j = \sum_{j=1}^{n} D_j e^{-\beta t_{ij}}$, a derivative of Figure 5.

Where,

$A_j$ = the active accessibility metric,

$D_j$ = a destination location,

$\beta$ = distance decay function, and

$t_{ij}$ = travel time between origin and destination.

This process is repeated for every origin-destination pair in the transit model. Once all O/D pairs have a score for their respective destination type, the full accessibility score for each destination type was calculated for each block group origin. To calculate the active accessibility, scores for each destination type are summed. This is repeated for all destination types except for hospitals.

Hospital scores are assigned utilizing their transit travel time alone without the use of the beta factor. The nearest hospital is assigned utilizing a weight of 1 divided by the transit travel time. Transit travel time was limited to 150 minutes, at which point the score would be zero and assumed a hospital is not accessible from the origin block group.

The healthcare score is a composite of hospital, mental health facilities, substance abuse centers, and urgent care facilities. Illustration of this score can be found in Figure 10.

## Level of Access

Level of access is determined by combining the scores for all four destination type components and weighting them to produce a Fixed Route Transit access score. As Figure 16 illustrates, scores are relative to the highest overall Fixed Route Transit score in North Carolina. However, these scores represent total numbers of accessible destinations and amenities, and these are further discussed in the *Driving and Non-Driving Accessibility in North Carolina* chapter.

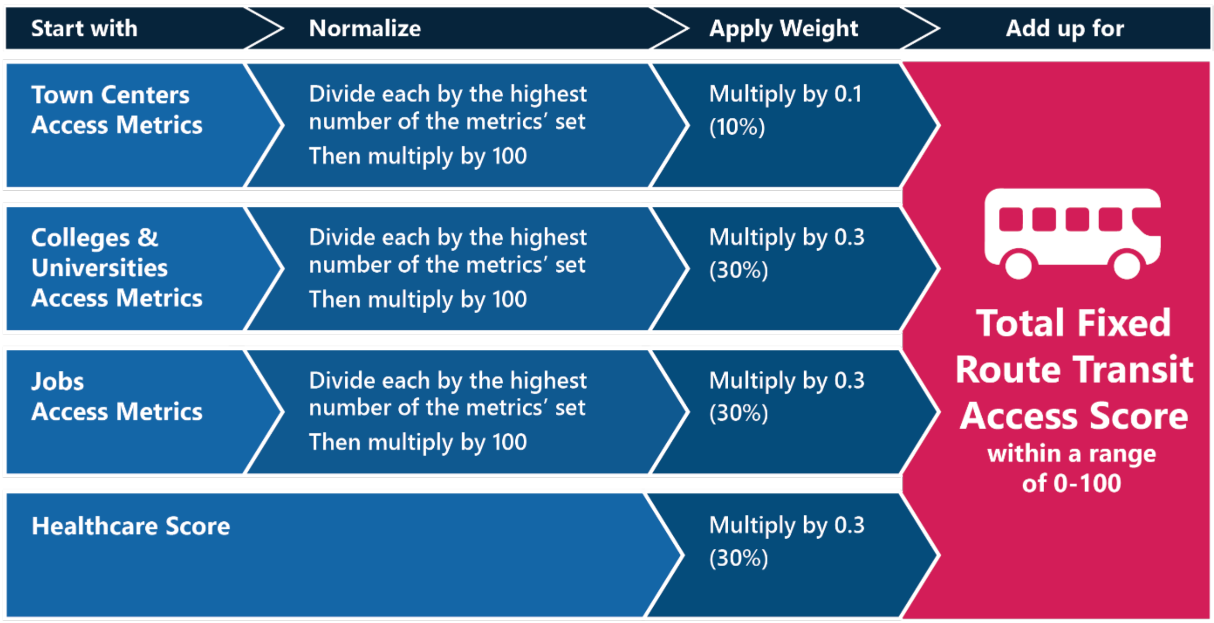


Figure 16. Graphic Illustration of Fixed Route Transit Scoring

### Level of Access Map

Figure 17 illustrates the statewide Fixed Route Transit accessibility scores.

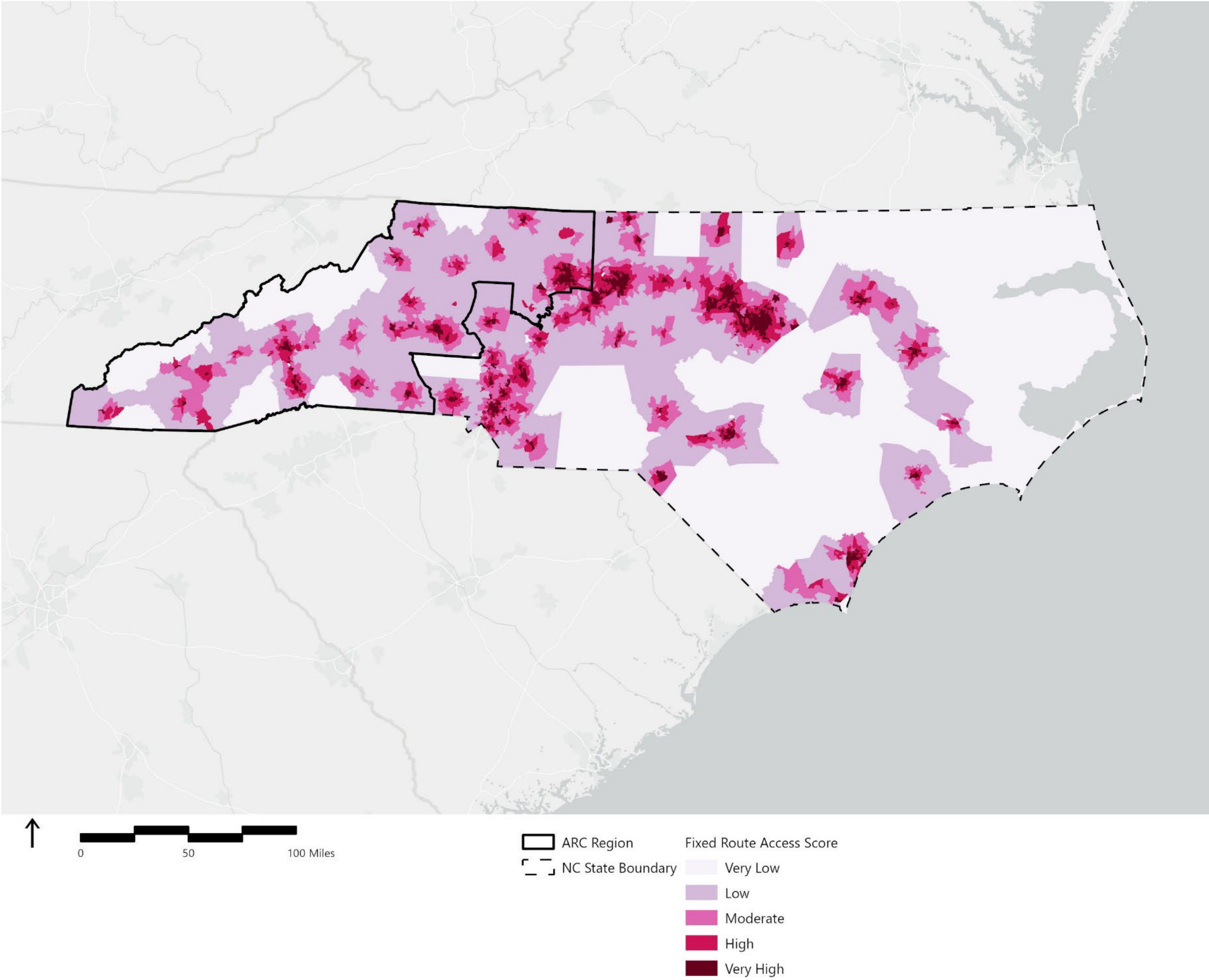


Figure 17. Statewide Fixed Route Transit Access Calculations

### Discussion of Results

Unlike the drive time access, fixed route transit access is much more localized due to the nature of the service provided. Block groups that have a stop located within or in proximity to its boundaries tend to have higher fixed route transit access than those who do not. For residents in block groups without a stop nearby, they are forced to walk to the closest stop, adding additional time to their journey. The same is true for their destination – the further the destination from a stop, the less accessible. The headway of each transit line also plays a significant role in the transit accessibility of a block group. More frequent service correlates to higher levels of transit access, whereas longer headways between transit (bus and light rail) decrease the accessibility. A final factor in transit access is that of connectivity between routes.

Urban cores tend to have the highest levels of access compared to other regions of the state. Larger urban centers have the largest concentration of high access fixed route transit, as can be seen in Raleigh, Durham, Chapel Hill, Greensboro, Winston-Salem, Fayetteville, and Charlotte. Even moderate-sized cities such as High Point, Hickory, Goldsboro, Rocky Mount, and Greenville have relatively large concentrations of high transit access. As shown in Figure 17, outside of these high access zones, the relative accessibility to destinations decreases significantly the further one goes from an established transit line. Thus, proximity to existing transit lines with a nearby stop on a high-frequency route with opportunities for connections yields the highest levels of accessibility.

## Level of Opportunity

As noted in Figure 13, fixed route transit access (as well as all other non-driving modes for personal access) is based on access deficit, as well as access deficit multiplied by TDI, and access deficit multiplied by the proportion of zero vehicle households. As seen in Figure 18, fixed route transit access is concentrated in urban cores and steeply declines as the context becomes more suburban and rural. These suburban and rural contexts are where opportunity for improvement is concentrated. Further, Figure 19 and Figure 20 illustrate opportunity for communities with access to fixed route transit and communities without access to fixed route transit respectively.

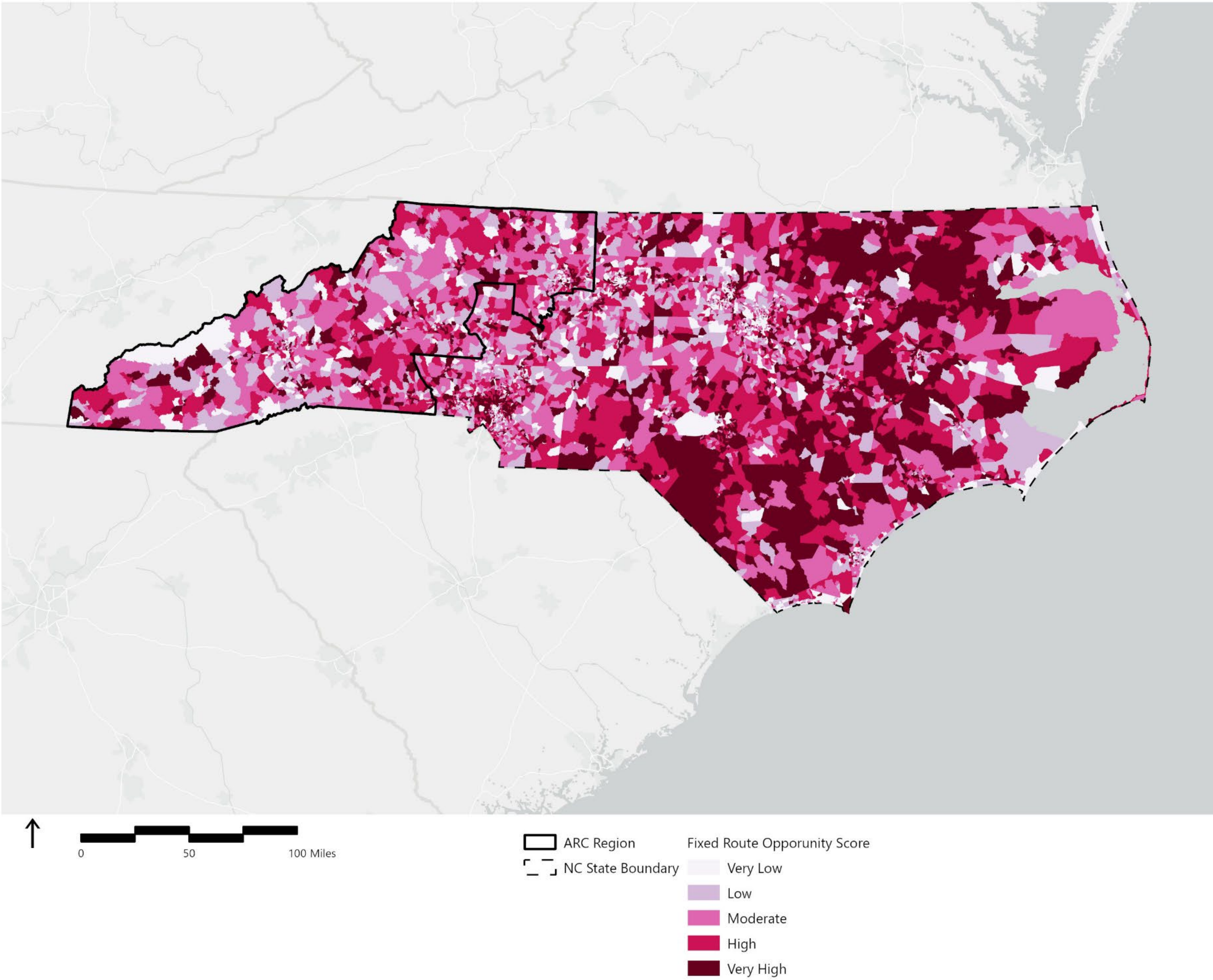


**Figure 18. Statewide Fixed Route Transit Opportunity Calculations**

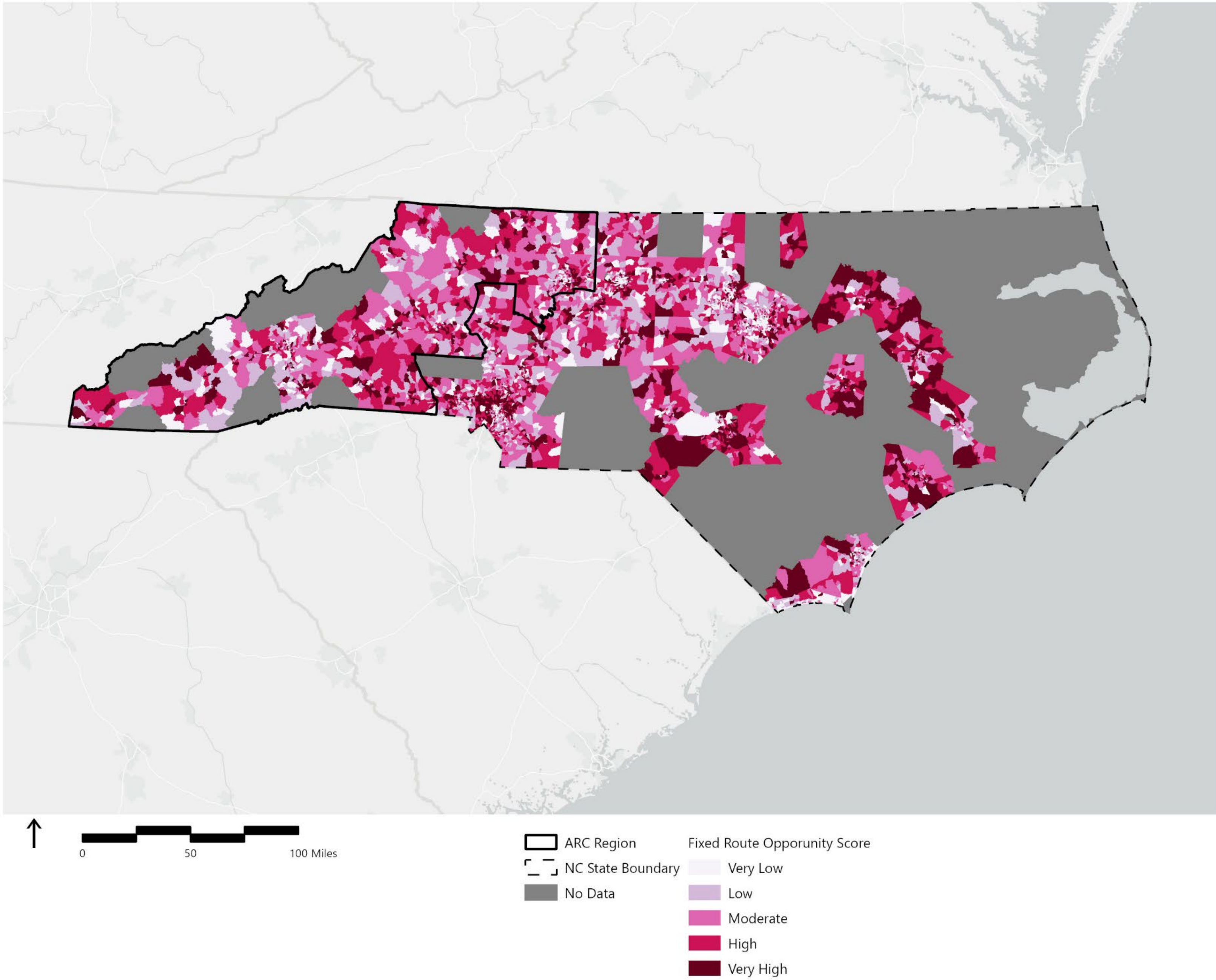


Figure 19. Statewide Fixed Route Transit Opportunity Calculations (Communities with Access)

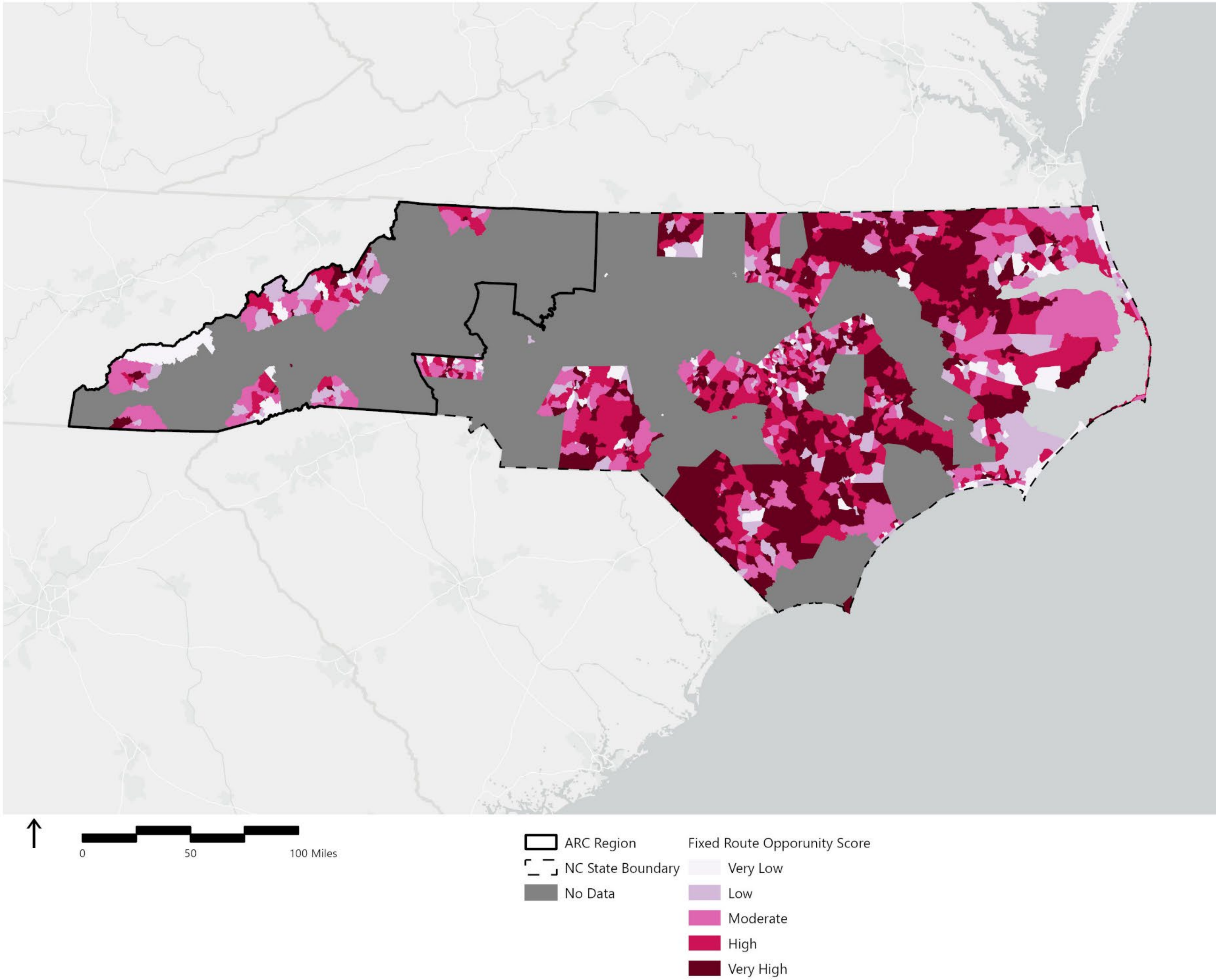


Figure 20. Statewide Fixed Route Transit Opportunity Calculations (Communities without Access)

First, focusing on areas that have existing fixed route transit, the highest opportunity block groups are those with high concentrations of zero-vehicle households and transportation disadvantaged residents. This is evident in locations, such as Charlotte, where the highest opportunities are in the 'crescent', a location of historically disadvantaged communities that circle the central business district, or Durham, where there is a high concentration of transportation disadvantaged residents and zero vehicle households. Additional lower opportunity zones tend to radiate away from these areas; thus, these opportunity corridors would benefit most from improvements. Treatments that would increase access would include more frequent service, new routes, additional connections between routes, and optimization of routes between residential and commercial/office destinations.

Locations that do not already have existing fixed route transit yet have high opportunity, and a variety of options may be available to provide additional access. The most prevalent option could be microtransit, where the City of Wilson has recently implemented its new system. Due to its small size, the City recently removed its fixed route system in favor of microtransit that would be more responsive to residents' needs. Wilson is an example of a high opportunity city, where the impacts of microtransit would benefit the needs of the community without the costs and rigidity of fixed route transit. Additional options would be the implementation of fixed route or deviated fixed route transit along commercial corridors and denser residential areas that would connect neighborhoods to commercial districts and major destinations.

As shown in the opportunities map, there are a number of small rural towns and block groups that would benefit from fixed route transit. However, due to their rural nature and excessive cost of public transportation, these areas may not be suitable for transit as discussed above. Instead, a focus on increased demand-response transit options may be appropriate to fulfill rural residents' needs.

# Demand Response Transit

The Demand Response Transit analysis included components benchmarked relative to peer groups (see *Demand-Response Transit Providers* for more details), as well as components based on normative thresholds statewide.

## Accessibility Scoring

Demand response transit access shifts the focus from the number of destinations accessible to relative and normative metrics. Relative metrics examined factors of service capacity, service availability, and service connectivity, whereas normative metrics examined the delay of a ride request to the ride occurrence and scheduling options. Relative metrics were gathered from OpStats, and normative metrics were gathered from a survey of all demand response transit providers in North Carolina.

### Relative Metrics

This study used four relative metrics within three relative accessibility categories. Service capacity answers the question of how much service is delivered relative to the size of the service area population. To analyze service capacity, this study used vehicle seat hours per capita. Service availability seeks to understand how accessible the demand response transit service is in a given weekday or throughout the year. Metrics for service availability include: 1) total transit service days; and 2) operating hours per day. Finally, service connectivity reviews how many potential connections to adjoining transit services are realized. The research used a service-wide connectivity score based on the proportion of providers that interact with neighboring providers.

### Normative Metrics

This study also applied two normative accessibility metrics: same day service availability and number of scheduling options. Service providers were assigned a binary value (i.e., "1") if they offered same day transit services; no score (i.e., "0") was assigned if they do not. Service providers were also assigned a "1" if they offered more than one method for scheduling a transit trip, as well as a "0" if they offered only one method.

## Level of Access

Level of access is determined by combining the scores for all six metrics and weighting them to produce a Demand Response Transit access score. All metrices were scored on a scale of 0 to 100 based on the supply relative to their peers for relative metrics and established thresholds for normative metrics. Values of each metric were then weighted by 1/6 of their relative or normative score and then summed to create a demand response transit access score. As Figure 21 illustrates, this score allows transit providers to be compared with each other within their peer groups and should not be expanded to analysis outside of the peer groups.

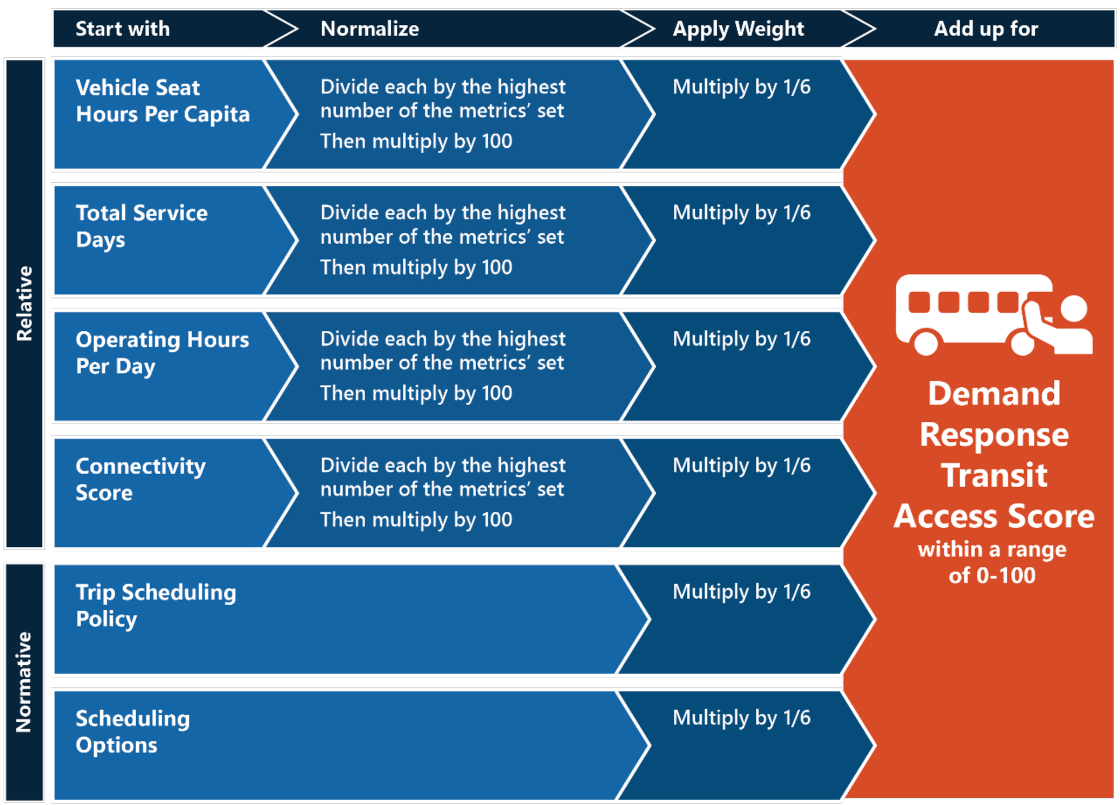


Figure 21. Graphic Illustration of Demand Response Transit Scoring

### Level of Access Map

Figure 22 illustrates the statewide Demand Response Transit accessibility scores.

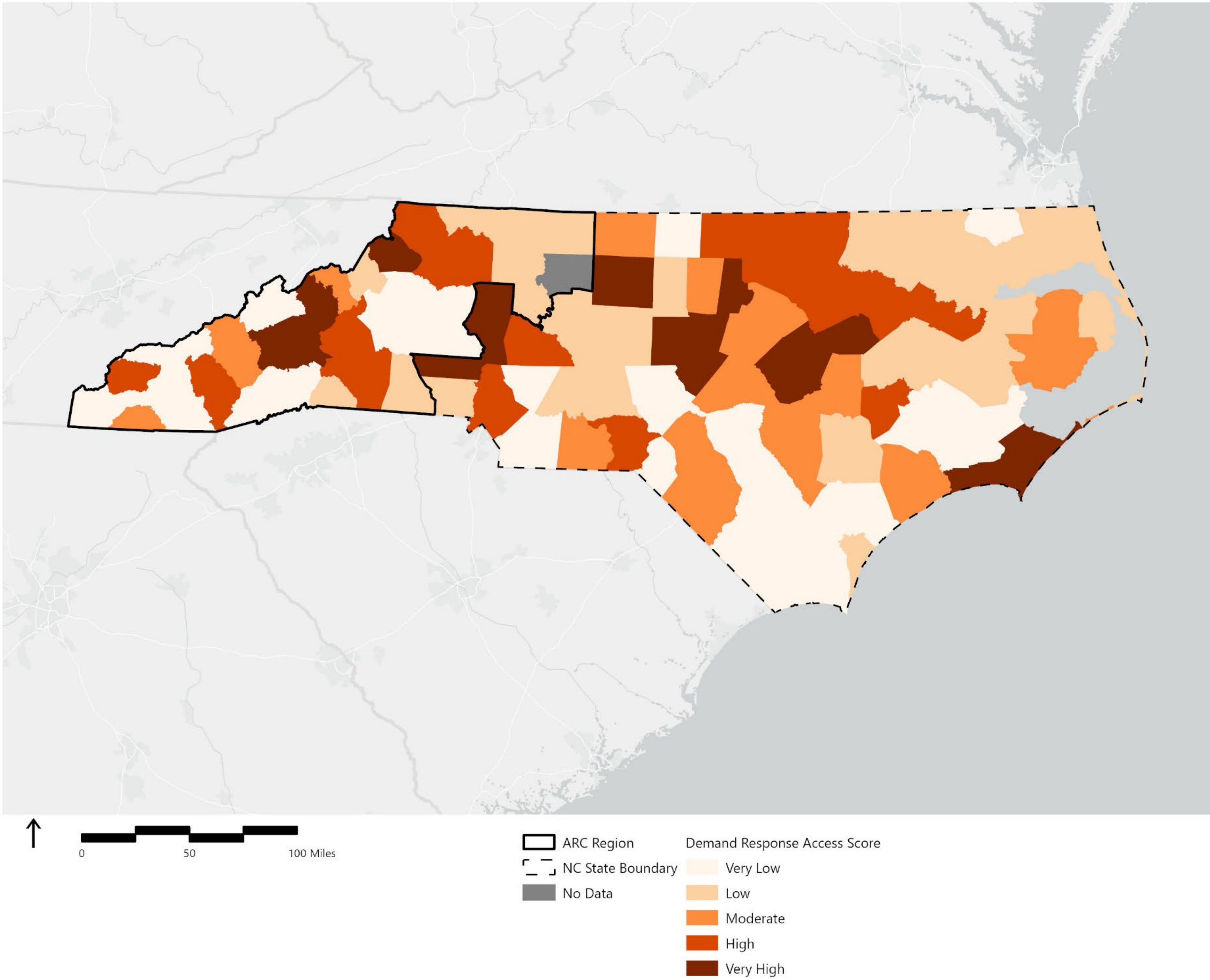


Figure 22. Statewide Demand Response Transit Access Calculations

### Discussion of Results

The level of access for demand response transit is based at the county level rather than the block group level and is categorized and compared to their peers rather than all counties in the state. As shown in Figure 22, there is not strong correlation between county type (Urban, Suburban, Rural) or location (Appalachia, Piedmont, Coast). Locations of high access include those served by Johnston County Area Transit, Chatham Transit Network, Lee County (COLTS), Go Durham/Durham County, Guildford County, Iredell County (ICATS), Lincoln County, AppalCART Boone, Buncombe County, Yancey County Transportation, and Graham County. A mix of urban, suburban, and rural transit networks scored well for relative access across the state.

Numerous transit agencies with larger urban cores did not perform well. Examples of these counties include New Hanover (Cape Fear Public Transportation Authority), Greenville (Pitt Area Transit System), Craven County (CARTS), Cabarrus County, and the Western Piedmont Regional Transit Authority.

Of note, numerous rural demand response transit agencies performed well compared to their peers. Examples include KARTS, Person County (PATS), Carteret County, Hyde County, Ashe County, Graham County, McDowell County Transportation, and Jackson County.

## Level of Opportunity

As noted in Figure 13, demand response transit access (as well as all other non-driving modes for personal access) is based on access deficit, as well as access deficit multiplied by TDI and access deficit multiplied by the proportion of zero vehicle households. As seen in Figure 23 and Figure 24, demand response transit opportunity is highly correlated based on counties with highly active transit systems. Less accessible systems (relative to their peer agencies) provide more opportunity for accessibility investments.

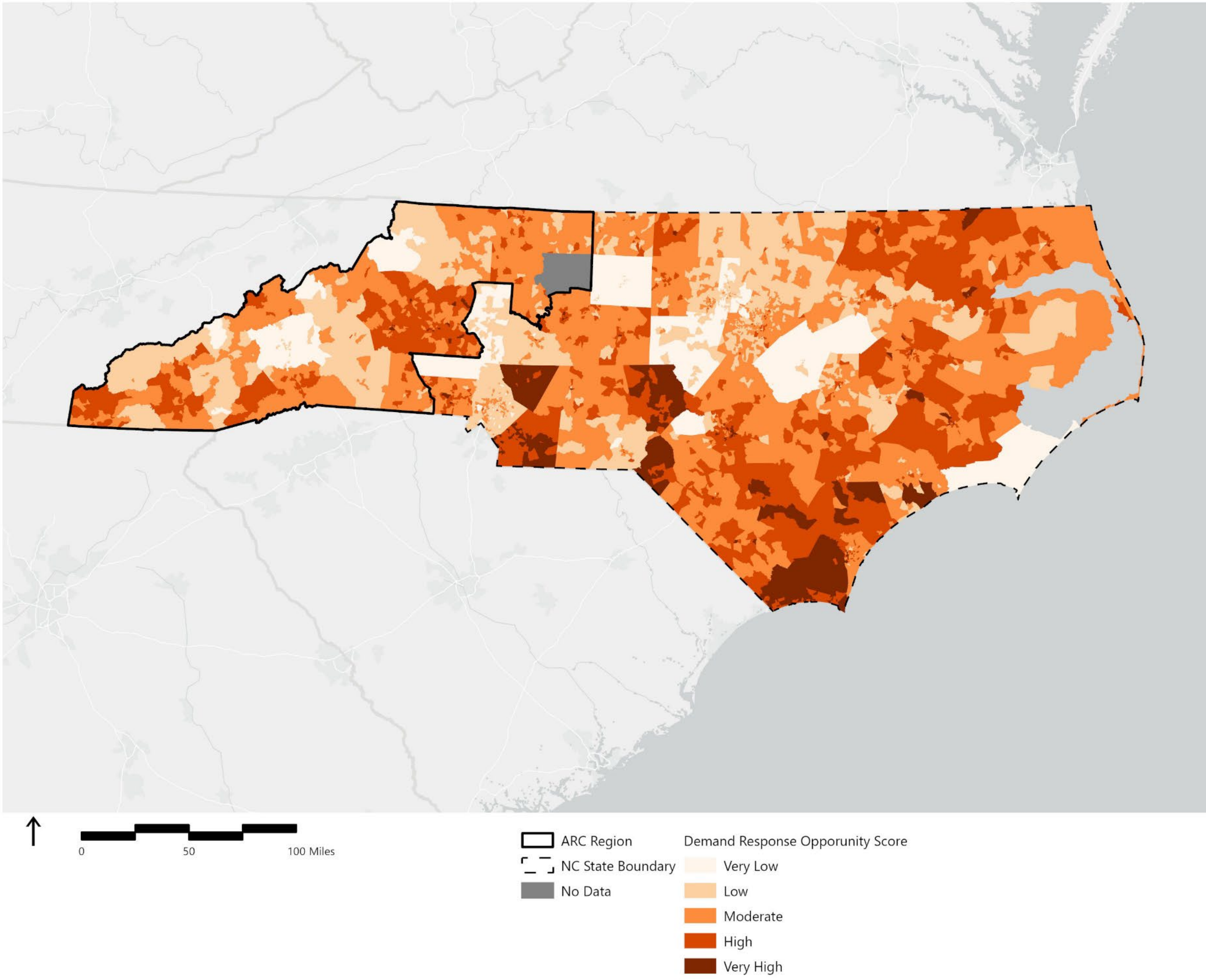


Figure 23. Statewide Demand Response Transit Opportunity Calculations

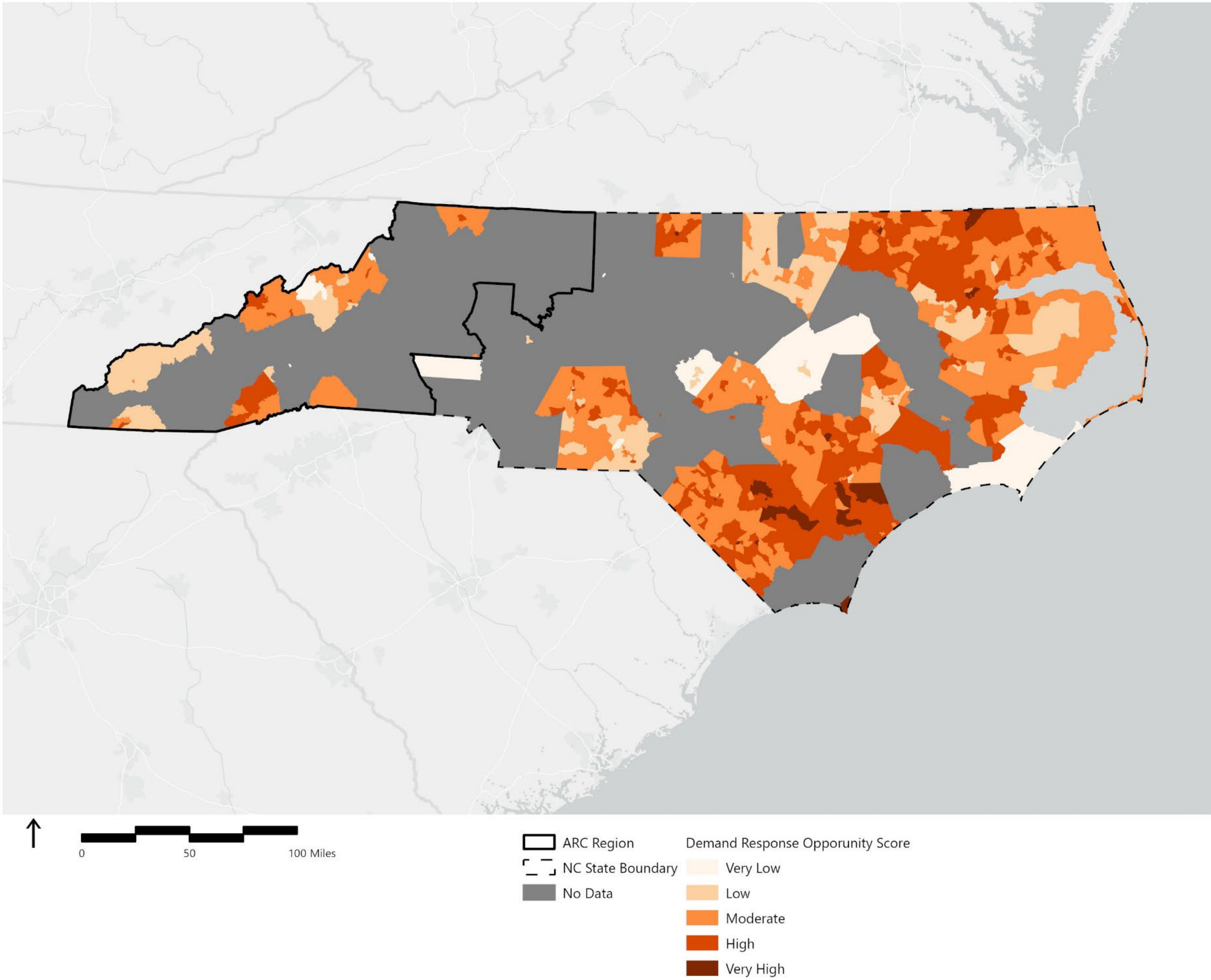


**Figure 24. Statewide Demand Response Transit Opportunity Calculations (Communities without Access to Fixed Route Transit)**

Greater opportunity is largely evident in the coastal region of North Carolina where high concentrations of transportation disadvantaged residents with limited opportunities to utilize fixed route transit live. As discussed with drive time access in these coastal communities, destinations are sparse and tend to cluster in moderately sized communities. Thus, for those who are without access to a private vehicle, accessibility to day-to-day destinations is limited without reliable and responsive demand response transit options.

As can be seen in Figure 23, level of opportunity for demand response transit is measured at the block group level, compared to the level of access metric which was measured at the county level. Block groups throughout the state with low levels of access also have large concentrations of transportation disadvantaged residents and zero vehicle households, which correlate with high or moderately high levels of opportunity. This is true even for block groups served by fixed route transit.

It should be noted that while block groups with high concentrations of transportation disadvantaged residents and zero vehicle households show high levels of opportunities, rural communities who do not meet this definition also show opportunity throughout the state. This is again due to their reliance on personal vehicles because of the limited roadway, transit, and bicycle and pedestrian networks. Changes in policy and operating hours in these rural counties would benefit these residents as well as targeted disadvantaged communities.

# Bicycle and Pedestrian

This research measured bicycle and pedestrian accessibility through four metrics, primarily focused on the accessibility of the network and infrastructure, rather than destinations. These metrics include roadway characteristics of a low-stress network, available infrastructure, roadway connectivity, and the neighborhood context.

## Network Metrics

### Low-Stress Network

Identification of a low-stress network includes posted speed limits, number of through lanes, and annual average daily traffic (AADT). Posted speed limits equal to 45 mph or less, roadways with daily traffic of under 9,000, and 4-lane or fewer roadways were identified as low-stress for pedestrian and bicycle comfort. These thresholds were identified from safety countermeasure literature, including the Federal Highway Administration's (FHWA's) *Bikeway Selection Guide* (Schultheiss, 2019) and *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (Blackburn et al, 2018). The proportion of roads that met these criteria relative to the total mileage of road centerlines in a block group produced a final low-stress network score.

### Available Infrastructure

To assess available pedestrian infrastructure, the research team developed a ratio of the total length of sidewalks to the total number of roadway centerline miles. The ratio ranged from zero (no sidewalks present in the block group) to two (sidewalks on both sides of the road for all roads in the block group). Bicycle and shared use facilities were not considered in this metric due to the lack of reliability of these data, but future analyses could be adapted to consider bicycle facilities as well.

### Roadway Connectivity

Roadway connectivity reviewed the density of bicycle and pedestrian-accessible intersections per square mile within block groups. Bicycle and pedestrian-accessible intersections would be those at-grade and not on access-controlled facilities. This metric was intended to measure the network connectivity and direct connections.

## Nearest Neighbors

The final metric is relative to the scores surrounding a particular block group to provide neighborhood context. This score is dependent on the block group's neighbors' scores for the three network metrics to understand how easily it would be for a pedestrian or bicyclist to reach destinations outside of their home block group. If the home block group has a low-stress roadway network, good connectivity, and available pedestrian infrastructure, but the surrounding block groups do not, a lower score would be assigned, lowering the entire score for bicycle and pedestrian access. Conversely, a home block group with a higher-stress network, poor connectivity, and little pedestrian infrastructure nestled in a neighborhood of higher performing block groups would receive a 'bonus' as residents can reach a more bicycle- and pedestrian-friendly network from their home. Neighborhood scores are weighted relative to the length of the boundary each neighboring block group has with the home block group.

## Accessibility Scoring

After calculating each of the four metrics, each score was transformed on a scale of 0-100 in relation to their performance to all other block groups in North Carolina. Then, each of the four scores were equally weighted at 25% of the total bicycle and pedestrian access score and summed together. This final weighting was then used as a basis for comparison of the block groups in the state.

## Level of Access

As Figure 25 illustrates, scores are relative to the highest overall bicycle and pedestrian access score in North Carolina.

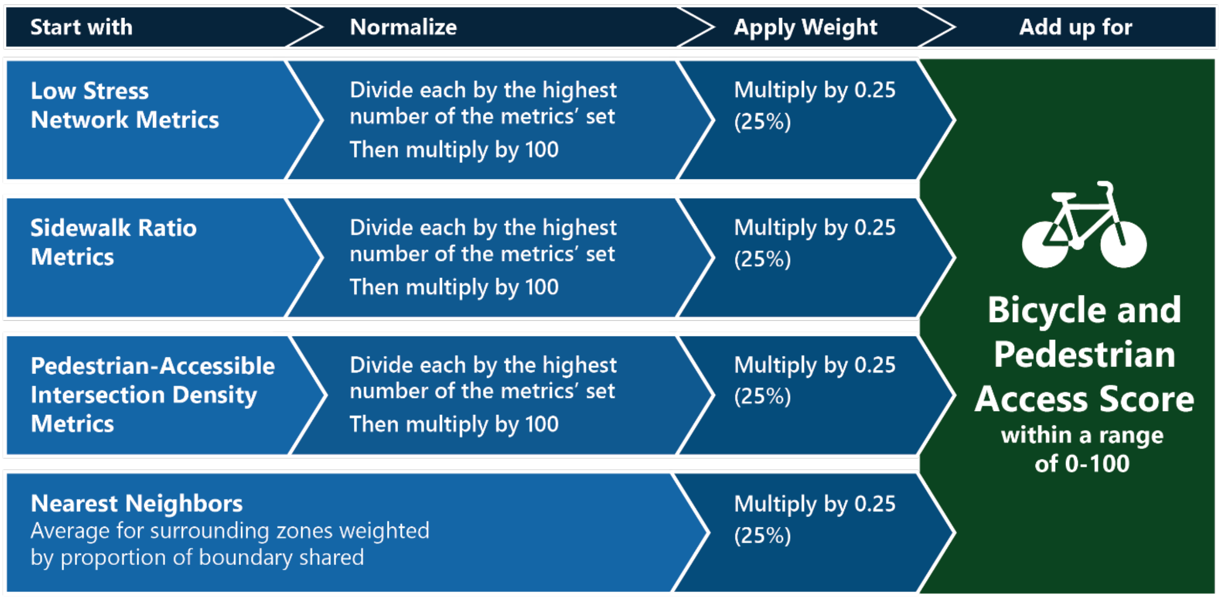


Figure 25. Graphic Illustration of Bicycle and Pedestrian Scoring

### Level of Access Map

Figure 26 illustrates the statewide bicycle and pedestrian accessibility scores.

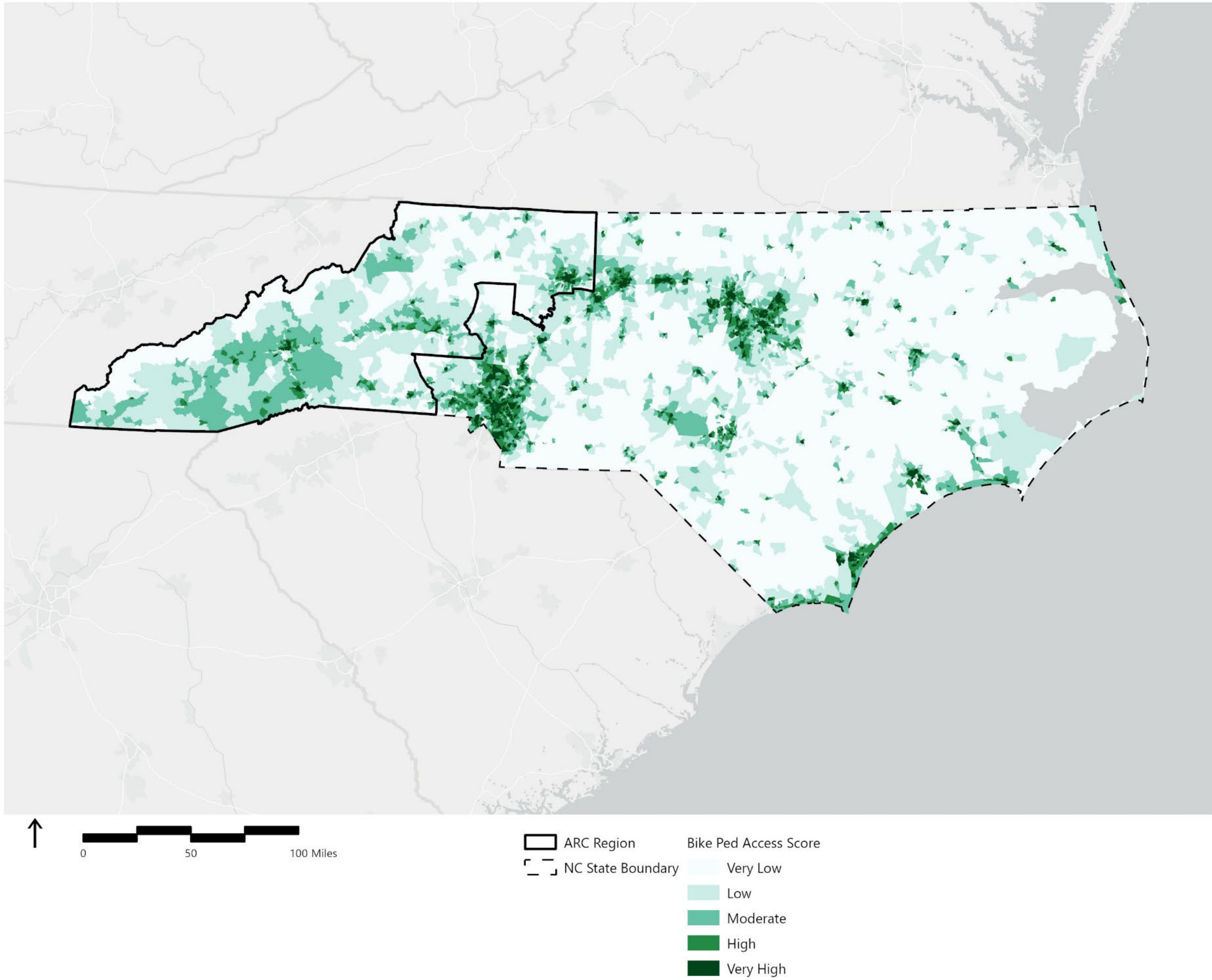


Figure 26. Statewide Bicycle and Pedestrian Access Calculations

### Discussion of Results

Bicycle and pedestrian access is primarily concentrated in the state's cities and towns. While it is evident that the state's largest cities, such as Charlotte, Raleigh, and Greensboro, perform well for bicycle and pedestrian accessibility, small towns across the state also perform well. In the coastal region, towns, such as Ahoskie, Edenton, Washington, Havelock, and Whiteville, have relatively high levels of access alongside larger towns and cities, such as Kinston, New Bern, Jacksonville, Wilmington, and Greenville. In the Piedmont, municipalities, such as Raeford, Hamlet, Wadesboro, Wingate, and Bessemer City, have downtown cores that are walkable and bikeable. The larger cities of the Piedmont, such as Charlotte, Winston-Salem, Greensboro, Durham, and Raleigh, have walkable and bikeable block groups that extend further out from the downtown core and into their inner suburbs. In Appalachia, small municipalities, such as Marion, Black Mountain, Canton, and Andrews, have walkable and bikeable block groups within and near their downtown core or main street.

For smaller municipalities of North Carolina, block groups encompassing the downtown core tend to have higher bicycle and pedestrian access where block lengths tend to be more compact, existing pedestrian and bicycle facilities exist, and roadways have lower traffic volumes and slower posted speed limits. In moderately sized municipalities, bicycle and pedestrian accessibility extends outside of the downtown core and into the inner neighborhoods and commercial areas where existing infrastructure is present and signalized crossings present pedestrians and bicyclists with safe opportunities to cross. Large municipalities have their bicycle and pedestrian accessible block groups extend far beyond their downtown core and commercial corridors because of their more complete pedestrian and bicycle networks, denser blocks, and a variety of local roadways that intersect higher order roads at traffic signals with bicycle and pedestrian signal heads.

## Level of Opportunity

As noted in Figure 13, bicycle and pedestrian access (as well as all other non-driving modes for personal access) is based on access deficit, as well as access deficit multiplied by TDI, and access deficit multiplied by the proportion of zero vehicle households. As seen in Figure 27, bicycle and pedestrian opportunity is highly negatively correlated with urban centers; rural and suburban locations tend to have the highest opportunity for improvement.

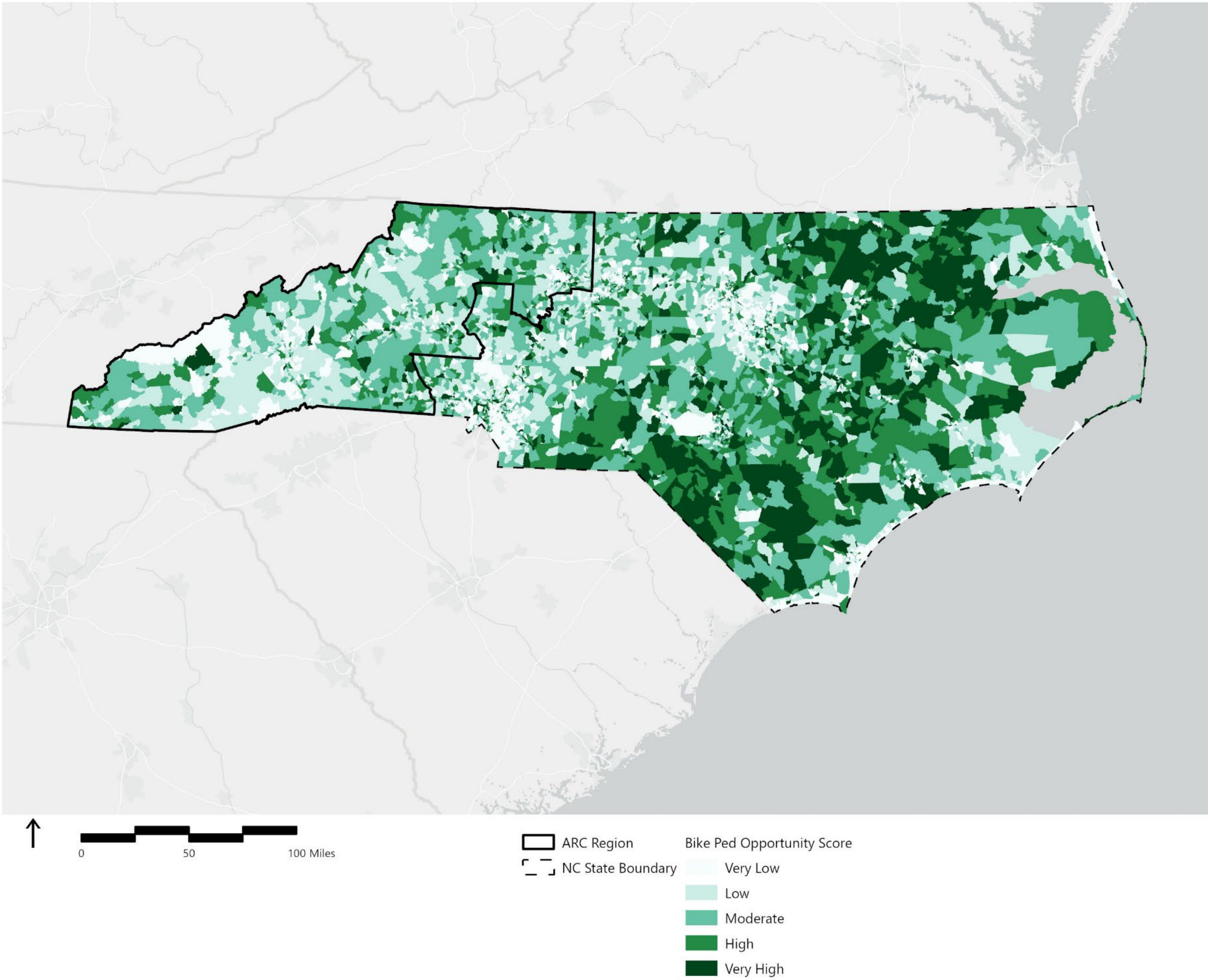


Figure 27. Statewide Bicycle and Pedestrian Opportunity Calculations

A large concentration of transportation opportunity for improving the bicycle and pedestrian access for North Carolina largely sits to the east of the I-95 corridor. A large factor is that disadvantaged residents lack a well-connected, accessible urban road network. There is also a high concentration of opportunity around the US-74 corridor between Lumberton and Wadesboro. On the western side of the state, there are moderate levels of opportunity compared to the eastern part of North Carolina. This is in part due to the lesser concentration of transportation disadvantaged residents despite the lack of pedestrian and bicycle facilities and disconnected roadway networks that also affect the east.

Within the urban areas of the state, there are still high levels of opportunities for improvements in bicycle and pedestrian facilities. These tend to cluster in historically disadvantaged communities with concentrations of transportation disadvantaged residents who may not have access to private vehicles.

# Business Access

Business access to destinations is defined as the ability to reach commercial airports, major seaports, and intermodal facilities for the purpose of shipping goods and the ability to hire an adequate workforce. This research measured access for business based on two overall criteria, access to freight and business destinations (e.g., ports and airports) and access to an educated and trained workforce.

## Freight and Business Destinations

For this study, five shipping destinations were considered: commercial airports, major seaports, inland ports, truck-to-rail intermodal facilities, and truck-to-air intermodal facilities. General aviation airports were excluded from the analysis due to lack of shipping volume through the ports. Facilities for analysis were limited to North Carolina, South Carolina, Georgia, Tennessee, Virginia, and West Virginia.

## Workforce Access

The availability of a potential workforce was measured through ACS data for all block groups in North Carolina. Due to the technical nature of manufacturing, delivering of services, and administrative and technological positions that industries bring to North Carolina, the available workforce was measured through additional education beyond K-12. As an associate or bachelor's degree is typically not necessary for a manufacturing position, this study used the ACS's definition of some college completed as a metric for additional education beyond K-12. Since on-the-job technical training is often employer provided or sponsored, this ACS classification of additional education would typically cover this level of training. The potential workforce was limited to those who are 25 and older due to data constraints by the ACS.

## Accessibility Scoring

The business destinations of commercial airports, major seaports, inland ports, and intermodal facilities were measured using ESRI's pre-built roadway network and nearest facility tool in ArcGIS. The nearest facility tool was set to find the nearest two facilities based on travel time for each of the business destination types from the centroid of each block group. Generally, two destinations are preferred as the closest facility may be closed or temporarily inaccessible, and a second destination helps account for resiliency in accessibility metrics. These two closest destinations per category were then combined into one score using the destination (i.e., non-workforce) equation in Figure 5.

All business destinations receive an accessibility score for each block group. For intermodal facilities, which include inland ports, truck-to-rail, and truck-to-air, accessibility scores are combined into one intermodal composite score. Each intermodal facility is transformed between 0 – 100 based on their relative access to all other block groups in North Carolina. A graphic representation of how the other intermodal composite score is calculated can be found in Figure 28.

Access to the workforce was measured in a similar fashion to Drive Time and Fixed Route Transit access for people in that each block group was measured from its centroid to all other block group centroids within 75 minutes. A decay function was then applied (Figure 5) to each accessible block group so that the workforce in closer proximity to the origin block group counts more than the workforce further away. The weighted accessible workforce of all accessible block groups was then summed.

To measure the level of business access, the four components of the composite scores were transformed, weighted, and summed, similar to those metrics in access for people. Each component, access to workforce, commercial airports, major seaports, and the composite intermodal facilities were transformed between 0 – 100 based on their relative access to all other block groups in North Carolina. The scores were then weighted so that access to the workforce accounts for 40% of the total level of business access and the remaining three components were weighted at 20% each. The weighted components were then summed for the final business access score.

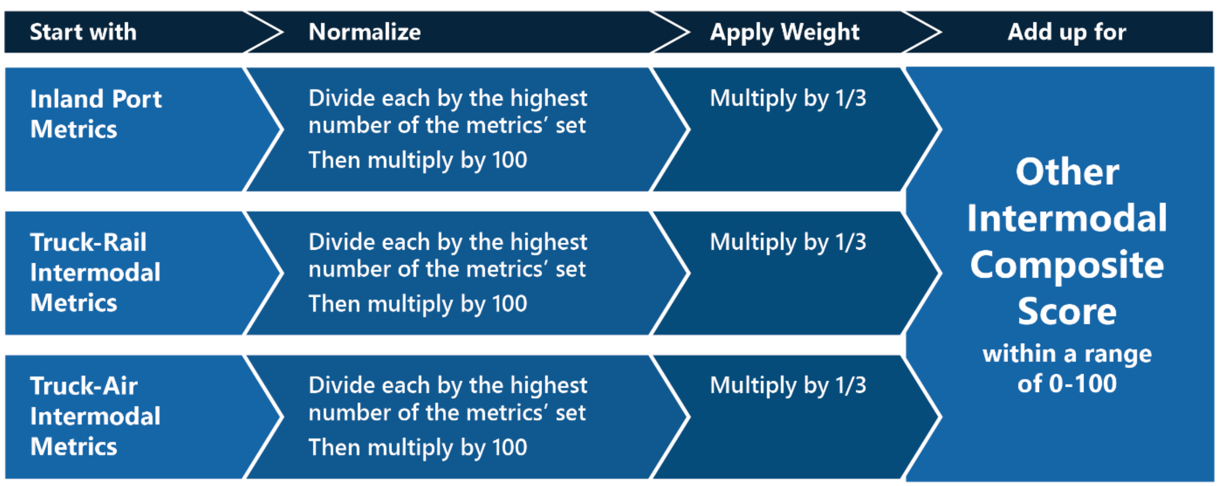


Figure 28. Other Intermodal Composite Score

## Level of Access

Level of access is determined by combining the scores for all four destination type components and weighting them to produce a Business Access score. As Figure 29 illustrates, scores are relative to the highest overall Business Access score in North Carolina.

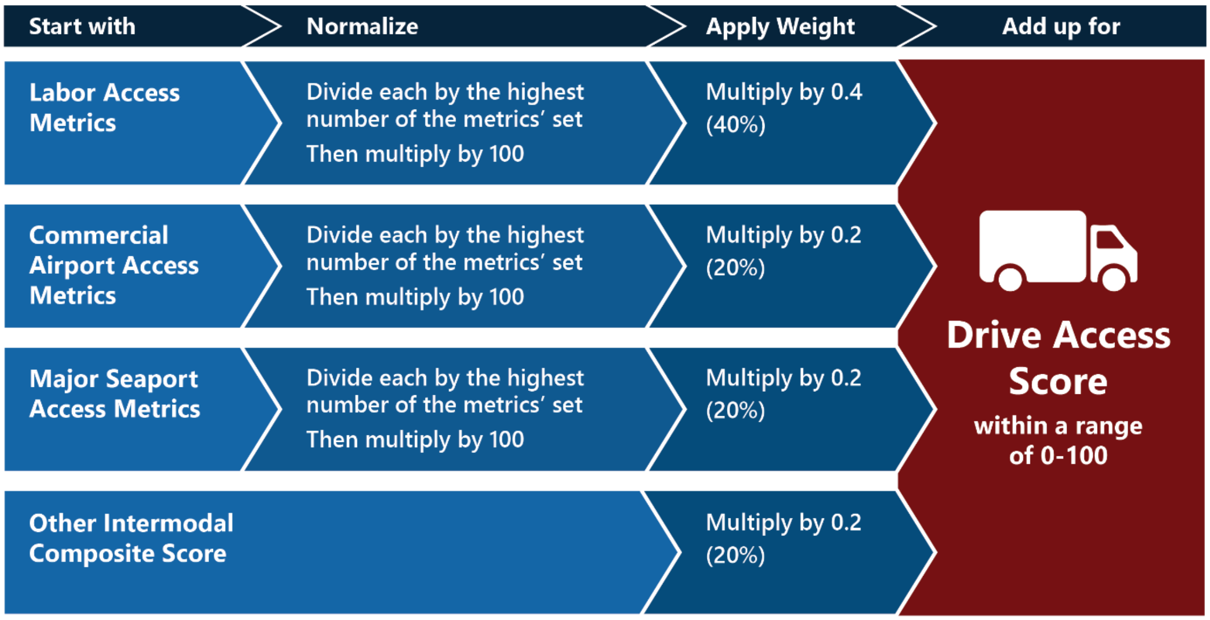


Figure 29. Graphic Illustration of Business Access Scoring

### Level of Access Map

Figure 30 illustrates the statewide Business Access scores.

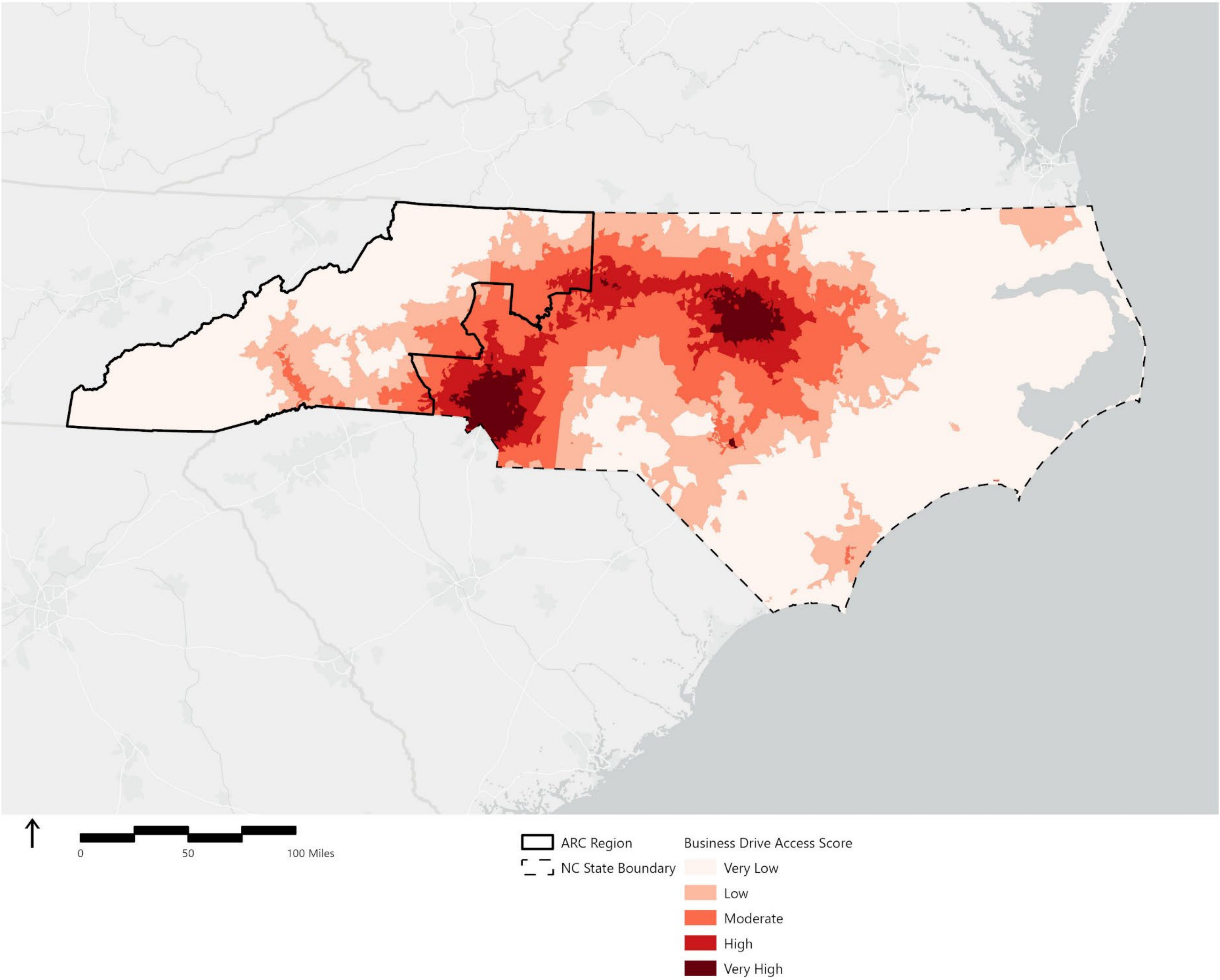


Figure 30. Statewide Business Access Calculations

### Discussion of Results

Business access in North Carolina is highest in and around the cities Charlotte and Raleigh and around the I-40/I-85 corridors. In this region of the state, the large urban centers of Charlotte, Raleigh, Durham, Greensboro, and Winston-Salem contribute to a large workforce. In these urban areas, there are also a large number of universities, community colleges, and technology and trade schools that enable residents with access to advanced education. In addition to population and education density, this region of the state has interstate mobility to move goods and services from their origin to their shipping destinations, whether it be airports, seaports, or intermodal facilities. In addition to roadways, this region also has a well-connected network of railroads to move goods between the urban cores. Another large component of business access along this corridor is the presence of commercial airports, such as Charlotte-Douglas, Piedmont Triad, and Raleigh Durham international airports.

Moving outside of the I-40/I-85 corridor, there is moderate access in the communities along interstates, where businesses can ship their goods along the highway to their primary shipping destination and for their workforce to commute into the facility. The I-95 corridor between Fayetteville and Rocky Mount has moderate business access in part due to the airport in Fayetteville and proximity to the ports of Wilmington and Morehead City. The US-74 and I-26 corridor between Charlotte and Asheville also has moderate business access due in part to the highway system.

Outside of the interstate system in North Carolina, there is low levels of business access. This is due in part of the low population density of educated workers outside of urban cores. Without a large presence of educated workers, businesses would have a harder time staffing their positions, limiting their ability to locate in a more rural community. Additionally, the lack of a robust roadway network that can carry freight quickly and efficiently to intermodal, air, and seaports hinders business' abilities to move their products at an affordable price that their competitors in more favorable locations of the state can do.

## Level of Opportunity

Figure 31 provides a graphical illustration of the opportunity calculation for business access. Business access is based on access deficit, as well as access deficit multiplied by a County Distress Tier ranking value. For the purposes of this analysis, the County Distress Tier rankings for each county for the years 2021, 2022, and 2023 were averaged to develop a county value. The final calculation produced a scaled value between 0.333 (for counties consistently in Tier 3 – the lowest level of distress) and 1 (for counties consistently in Tier 1 - the highest level of distress). Equation 4 provides the calculated value for calculating Business Access opportunity:

$$County\ Value\ for\ Opportunity = 1.333 - ((3\ year\ County\ Distress\ Tier\ average)/3)$$

(Equation 4)

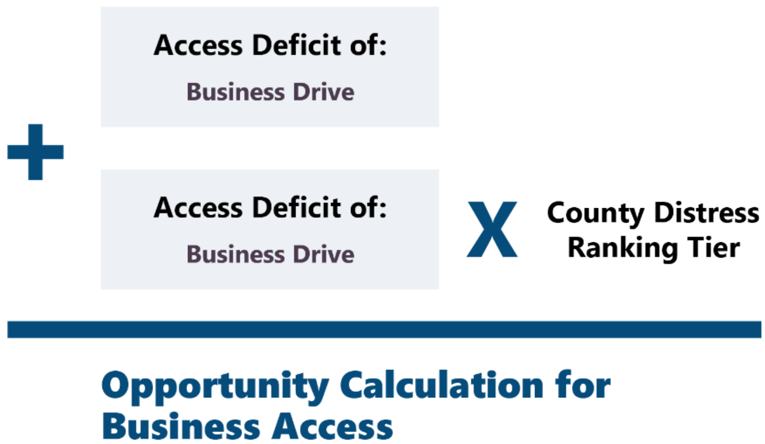


Figure 31. Opportunity Calculation for Business Access

As seen in Figure 32, counties in the Appalachia region and east of the state present the highest opportunities for improvement. High opportunity counties in the eastern coastal plain counties tend to be correlated with a high County Distress Tier ranking (Figure 9). However, high opportunity locations in the western part of the state tend to have lower scores as a result of limited access to commercial airports and major seaports. Although seaports are not a major concern for access in the Appalachia region, the combination of seaports and airports could speak to a lack of facility access more generally.

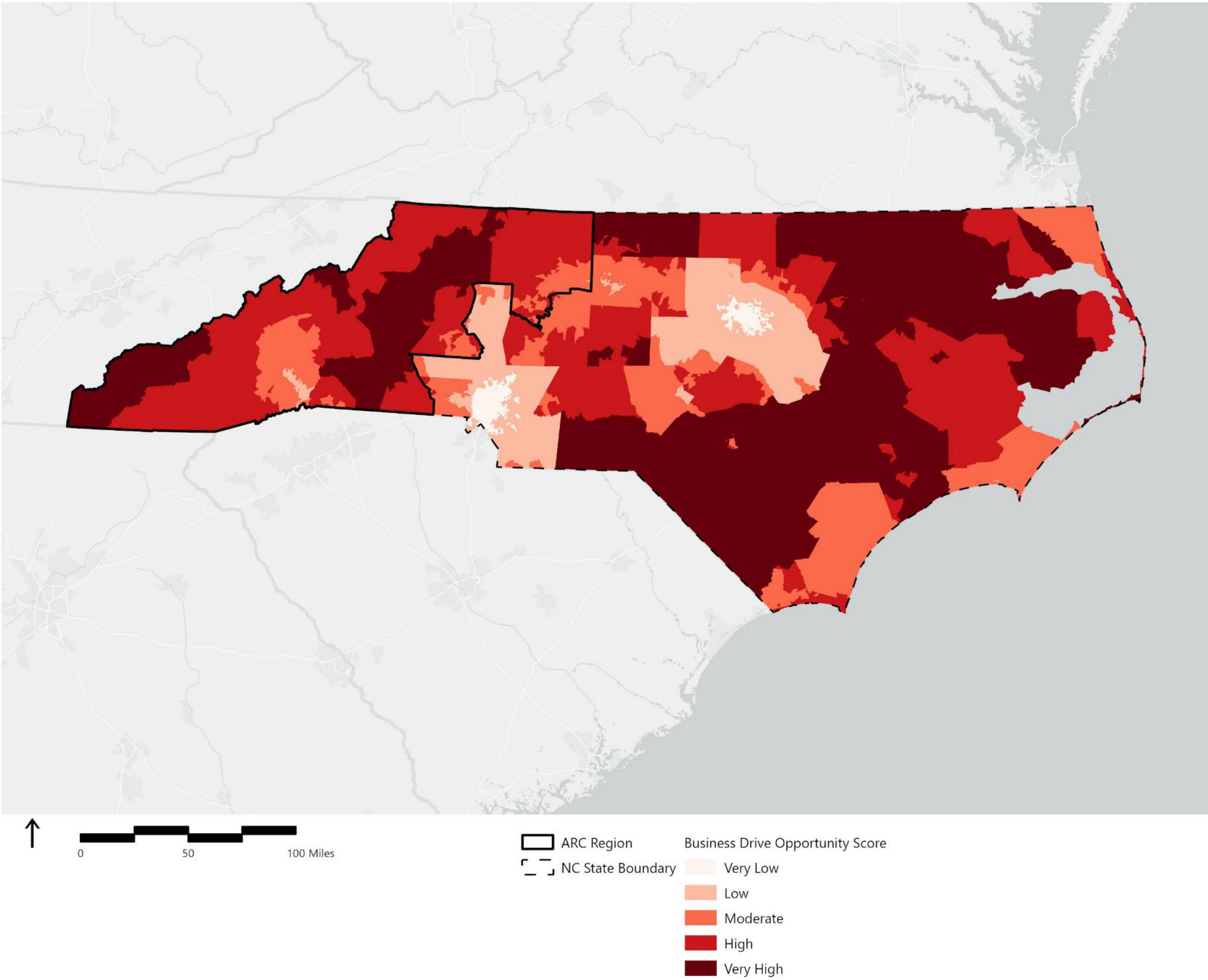


Figure 32. Statewide Business Access Opportunity Calculations

# 5

# Driving and Non-Driving Accessibility in North Carolina

This chapter outlines a modular approach for comparing accessibility across modes, particularly between personal driving and other modes of personal mobility. This includes four methods under two broad categories, 1) direct comparison between driving and non-driving and 2) relative comparison between driving and non-driving:

### Direct Comparison

1. Direct comparisons where the research methodology allows (i.e., travel times to the same destination type).
2. A categorical method for assessing personal accessibility for non-drivers.

### Relative Comparison

3. Relative comparisons in a mode scorecard.
4. A numerical method for weighting accessibility by impacted communities.

This will allow NCDOT to consider differences in access for driving and non-driving across the state.

## Direct Comparison

Direct comparison methods rely on objective comparisons between modes. In other words, how much more or less access is available to non-drivers compared to drivers, and can certain destinations be reached at all without a vehicle.

### Direct Comparison by Destination Type

The Access in Appalachia Pilot research used the same destinations and travel thresholds for personal accessibility by fixed route transit and personal driving. The methods applied to these modes, unlike demand response transit, bicycling, and walking, have travel times and decay functions that make direct comparison appropriate. NCDOT can use the results from this research to directly compare access to destinations by zone (e.g., Census block group) for these modes. For each zone, the number of accessible destinations by type, weighted using the decay function applied in the research methodology, can be compared.

Table 12 summarizes how driving and transit compare for each key destination type; for all destinations except for hospitals, if the ratio of Drive Score to Fixed Route Transit Score is greater than 1, these destinations are more accessible by driving for residents of a particular zone (i.e., *Zone i*). Likewise, a ratio less than 1 indicates these destinations are more accessible by fixed route transit.

**Table 12. Framework for Directly Comparing Accessibility by Mode**

| Accessibility by Destination for *Zone i* | Drive Score by Destination | Fixed Route Transit Score by Destination | Ratio of Drive Score to Fixed Route Transit Score | Difference between Fixed Route Transit Score and Drive Score |
|---|---|---|---|---|
| Town Centers<br>Colleges/Universities<br>Urgent Care<br>Mental Health<br>Substance Abuse | Number of destinations accessible by driving (weighted by decay) | Number of destinations accessible by fixed route transit (weighted by decay) | Number of destinations accessible by driving / Number of destinations accessible by fixed route transit | Number of destinations accessible by fixed route transit<br>–<br>Number of destinations accessible by driving |
| Jobs | Number of jobs accessible by driving (weighted by decay) | Number of jobs accessible by fixed route transit (weighted by decay) | Number of jobs accessible by driving / Number of jobs accessible by fixed route transit | Number of jobs accessible by fixed route transit<br>–<br>Number of jobs accessible by driving |
| Hospitals | 1 / Travel time by driving to the nearest hospital | 1 / Travel time by fixed route transit to the nearest hospital | (1/Drive time to hospital) / (1/Transit time to hospital)<br>=<br>Drive time to hospital / Transit time to hospital | (1/Transit time to hospital) - (1/Drive time to hospital) |

The average of these ratios provides a singular indicator for determining the level of accessibility for driving compared to non-driving for a given destination. Table 13 provides a sample evaluation for Census block group 501.02 in Downtown Raleigh.[19] Despite this block group having a relatively high level of access for fixed route transit, drivers have substantially more access to destinations and jobs. For instance, drivers have access to roughly 11 times, or about 450,000, more jobs than fixed route transit riders.

[19] 2020 Census boundaries.

Table 13. Sample of Direct Comparison for Driving and Non-Driving Accessibility in Downtown Raleigh

| Accessibility by Destination for Block Group 501.02 | Drive Score by Destination | Fixed Route Transit Score by Destination | Ratio of Drive Score to Fixed Route Transit Score | Difference between Fixed Route Transit Score and Drive Score |
|---|---|---|---|---|
| Town Centers | 21.31 | 0.14 | 152.21 | -21.17 |
| Colleges/Universities | 10.31 | 1.38 | 7.47 | -8.93 |
| Urgent Care | 21.16 | 1.26 | 16.79 | -19.9 |
| Mental Health | 14.39 | 1.66 | 8.67 | -12.73 |
| Substance Abuse | 31.49 | 1.50 | 20.99 | -29.99 |
| Jobs | 496,989 | 44,908 | 11.07 | -452,081 |
| Hospitals[20] | 0.13 (7.8 minutes) | 0.03 (37.0 minutes) | 4.7 | -0.1 |

## Categorical Access

A final method for determining access, particularly focusing on access for non-drivers is categorical travelsheds. Each of the analysis methods described in this research produce a travelshed by mode to specific destinations. These can be used for NCDOT prioritization programs. Figure 33 demonstrates how this can be applied to essential healthcare destinations, hospitals, and urgent care centers. This assessment produces a three-tiered categorical framework for determining personal access for non-drivers:

1. **Access with Fixed Route Transit and Biking/Walking:** This category indicates the highest level of access for all persons in a community. People in this block group can access a hospital or urgent care facility within a 75-minute transit ride and a 1-mile bicycle or walking trip (excluding access-controlled facilities where bicyclists and pedestrians cannot travel). Persons without access to a personal vehicle have more than one option available to them to complete their trip.
2. **Access with Fixed Route Transit or Biking/Walking:** This category indicates a somewhat reasonable highest level of access for all persons in a community. People in this block group can access a hospital or urgent care facility within a 75-minute transit ride or a 1-mile bicycle or walking trip. Persons without access to a personal vehicle would be able to accomplish their travel, but they may be sensitive to limited transit schedules or hindered by other personal mobility limitations.
3. **Access with Personal Vehicle or Demand Response Transit Only:** For these portions of the state, persons without access to a personal vehicle are limited in their access. They are dependent on others with a personal vehicle or demand response transit. These locations can help inform where multimodal improvements are most needed for North Carolinians.

[20] Note that hospital access is 1 divided by the travel time to the nearest facility in minutes.

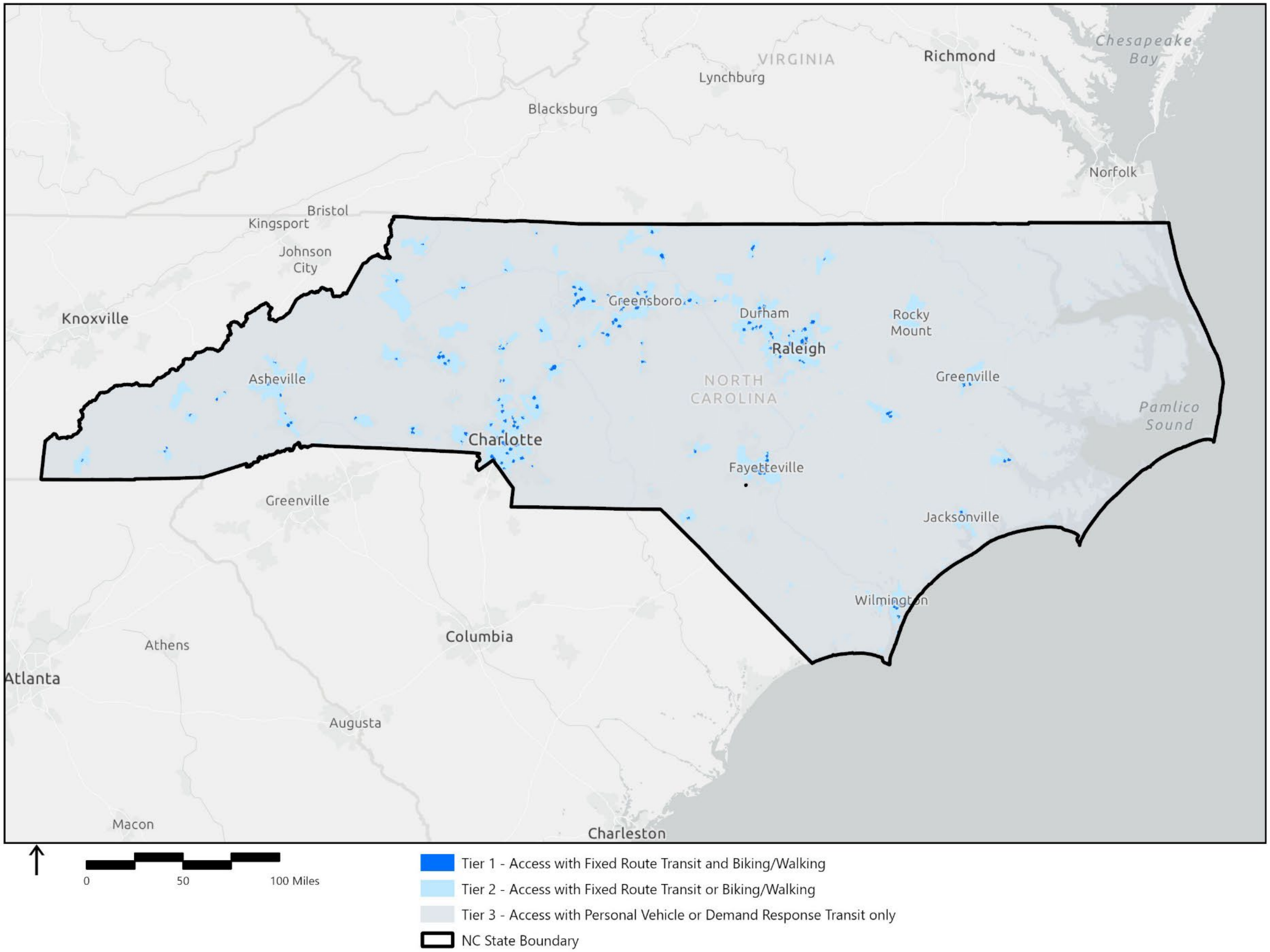


Figure 33. Direct Comparison of Multimodal Access to Essential Healthcare Destinations

*Appendix A-4, Categorical Access by Tier and County*, provides a distribution of population by county within each of the three aforementioned tiers. Counties with a higher population in Tier 1 have greater access to essential healthcare, while higher populations in Tier 3 have significantly lower access. This approach can be applied to any combination of destinations in addition to healthcare.

## Assessing Disparity

Direct comparison metrics lend themselves to quantifying and comparing disparities between drivers and non-drivers. In other words, how much more difficult (or easy) is it to be a non-driver relative to being a driver. Using the examples in Table 13 and Figure 33, this disparity can be mapped in terms of access to healthcare destinations. Table 13 shows that the typical driver in the example downtown Raleigh block group can reach nearly 20 more urgent care centers and reach a hospital nearly 30 minutes faster than the typical fixed route transit rider. Figure 33 illustrates the use of this method to map the disparity statewide and show where reliance on driving is highest.

Figure 34 maps this disparity regardless of the ability to bike or walk to a healthcare facility, and Figure 35 refines where this disparity exists and excludes areas where an individual could potentially bike or walk. Mapping disparities lend themselves to individual destination types, and additional disparities can be mapped by destination type.

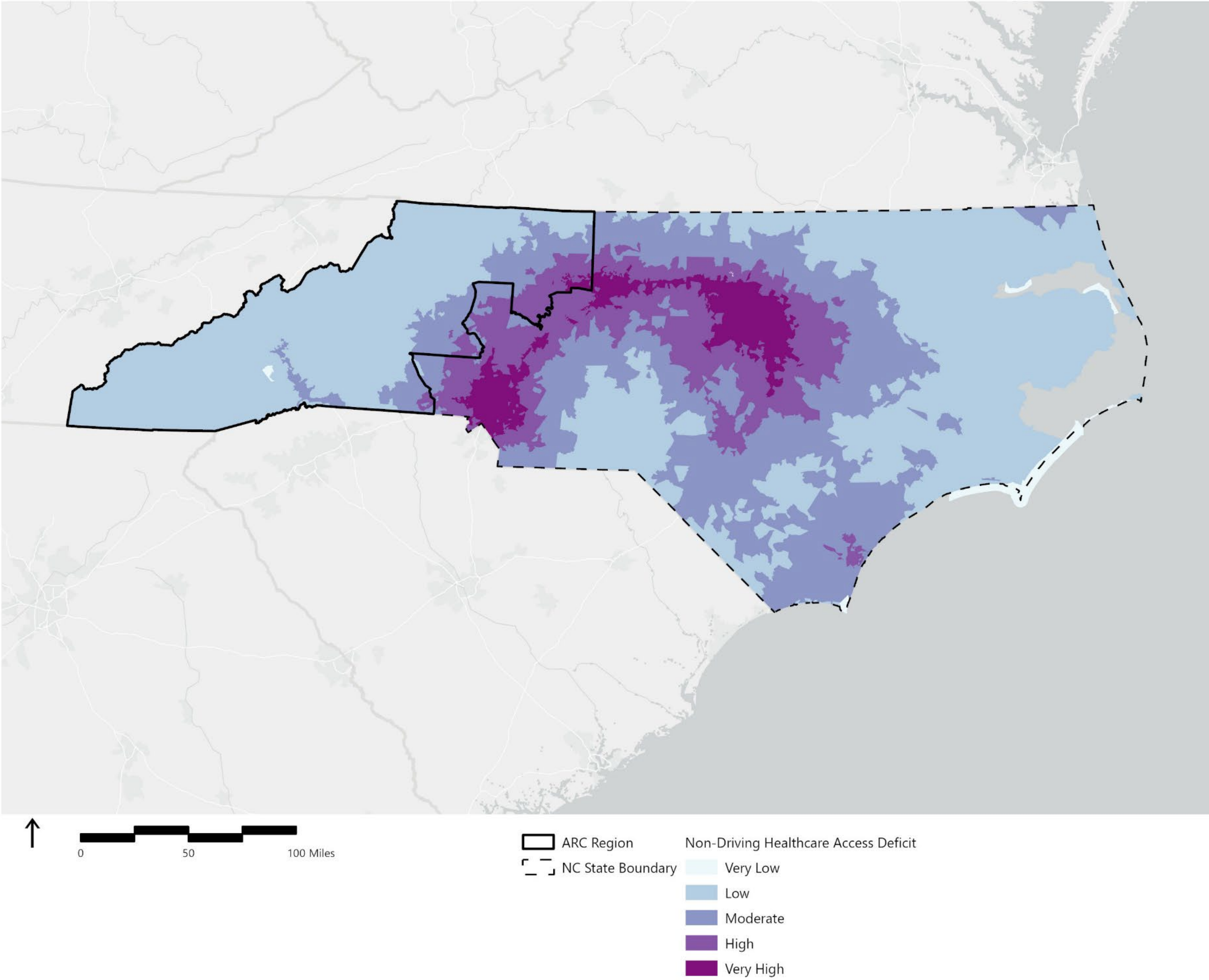


Figure 34. Direct Comparison of Access Deficit to Healthcare Facilities (Table 12)

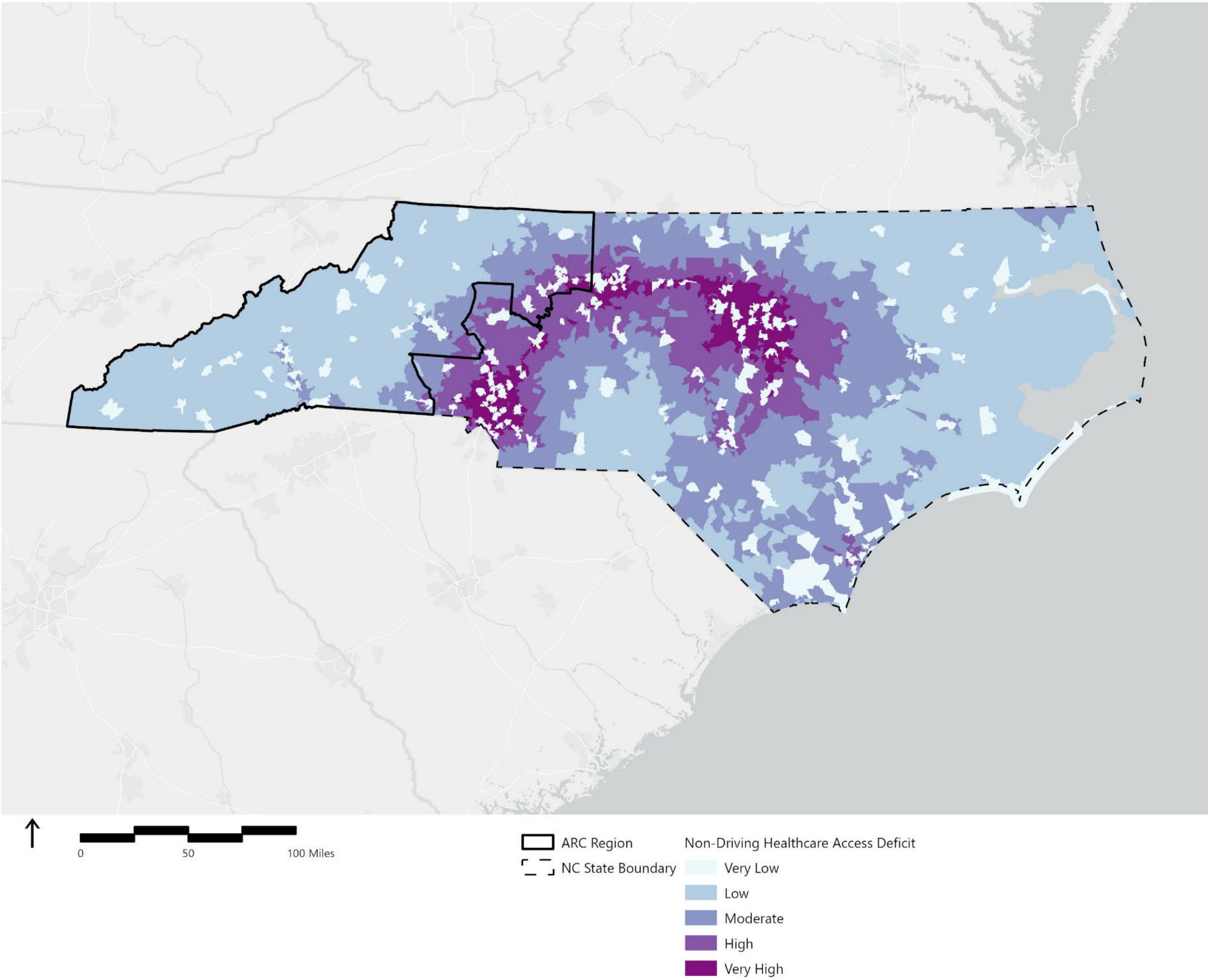


**Figure 35. Direct Comparison of Access Deficit to Healthcare Facilities Outside of Biking/Walking Distance**

# Relative Comparison

Relative comparison methods compare how access compares between different communities within a single mode. In other words, for instance, how much more or less access is available to fixed route transit riders in one block compared to another. Although these metrics are not directly comparable across modes, they can be combined with specific populations (i.e., zero vehicle households) to understand the accessibility conditions for a specific community.

## Relative Comparison of Access Quality Statewide

Although fixed route transit and personal driving access metrics are directly comparable, demand response, biking, and walking require more relative comparisons. Rather than being travel-time based, the demand response and walking and biking access metrics are primarily focused on service and infrastructure quality and are thus not directly comparable to the time-based metrics for fixed route transit and driving. Demand response transit provides access to nearly any potential destination (within a service area), but the convenience and value of this option is mediated by the level of service supply and various service scheduling constraints captured by the access metric. Conversely, biking and walking can be used at any time, but the ability to reach a destination is mostly limited to the area in proximity to a person's home or place of work and by the quality, comfort, and safety of available infrastructure.

To overcome this mismatch, NCDOT can use the research metrics in this report to develop a scorecard that compares the relative accessibility by mode. All modes receive a score between 0 and 100; a 0 indicates that a zone has the worst accessibility for that mode in the state, while a 100 represents the zone with the highest accessibility in the state (Table 14). Note that for Demand Response, four out of six metrics are benchmarked within peer agency groups, so that the comparison is relative to peers statewide. Since metrics are relative, a Pedestrian and Bicycle Access Score higher than a Drive Access Score in Boone, NC does not mean that biking and walking provides greater accessibility than driving in that particular zone; rather, it indicates that biking and walking accessibility is high relative to other zones when compared to same relative accessibility for driving.

Table 14. Relative Access Scorecards for Sample Zones.

| Zones | Drive Access | Fixed Route Transit Access | Demand Response Transit Access | Pedestrian and Bicycle Access |
|---|---|---|---|---|
| Downtown Raleigh<br>State Capital<br>(Block Group 501.02) | 81.26 | 83.85 | 53.48 | 67.78 |
| Downtown Wilmington<br>Major Natural Boundary<br>(Block Group 113.01) | 28.91 | 42.22 | 46.52 | 52.07 |
| Downtown Boone<br>Rural University Context<br>(Block Group 9205.01) | 15.12 | 14.28 | 86.73 | 47.44 |
| Statesville<br>Suburban Residential<br>(Block Group 601.03) | 63.29 | 4.51 | 66.7 | 40.40 |
| Greensboro<br>Suburban Commercial<br>(Block Group 126.08.2) | 76.53 | 37.1 | 75.99 | 33.80 |
| Henderson County<br>Rural<br>(Block Group 9301.03) | 25.75 | 0.23 | 43.54 | 28.86 |

## Relative Comparison of Access for Communities

NCDOT can also consider the relative access of a particular zone relative to the community context and the residents that may need multimodal access. This method weights non-driving access by the percentage of households without a car and weights driving access by the percentage of households with cars (Table 15). The non-driving access score weights transit and pedestrian/bicycle access evenly. To determine transit access, NCDOT would apply the higher access score between fixed route or demand response transit. As above, each of the individual modal metrics describe the relative access of a zone, compared to statewide.

Table 15. Community Access Comparison Calculation

| Zone | Drive Access (A) | % HH with Cars (B) | Non-Driving Access (C) | % of HH without Cars (D) | Composite Multimodal Score[21] |
|---|---|---|---|---|---|
| Zone i | 0-100 | 0-100% | 0.5*Max (Fixed Route, Demand Response Transit Score) + 0.5*Pedestrian and Bicycle Access Score | 0-100% | 0-100 = (A)*(B) + (C)*(D) |

Table 16 provides a sample calculation. In this example, downtown Raleigh and suburban Greensboro have the highest levels of multimodal access as a result of a high number of accessible destinations and available pedestrian infrastructure. Other locations may have lower levels of relative access as a result of major natural barriers or a fewer number of accessible destinations. Refer to the *Example Block Group Maps* section for aerial images of each block group's context. Figure 36 provides this calculation statewide.

Table 16. Sample Community Access Comparison

| Zone | Drive Access (A) | % HH with Cars (B) | Non-Driving Access (C) | % of HH without Cars (D) | Composite Multimodal Access Score |
|---|---|---|---|---|---|
| Downtown Raleigh State Capital (Block Group 501.2) | 81.26 | 91.4% | 75.82 | 8.6% | **80.79** |
| Downtown Wilmington Major Natural Boundary (Block Group 113.1) | 28.91 | 89.1% | 49.30 | 10.9% | **31.13** |
| Downtown Boone Rural University Context (Block Group 9205.1) | 15.12 | 86.9% | 67.09 | 13.1% | **21.93** |
| Statesville Suburban Residential (Block Group 601.3) | 63.29 | 97.9% | 53.55 | 2.1% | **63.09** |
| Greensboro Suburban Commercial (Block Group 126.08.2) | 76.53 | 79.5% | 54.89 | 20.5% | **72.10** |
| Henderson County Rural (Block Group 9301.3) | 25.75 | 96.8% | 36.20 | 3.2% | **26.08** |

[21] Final scores would be renormalized based on statewide values.

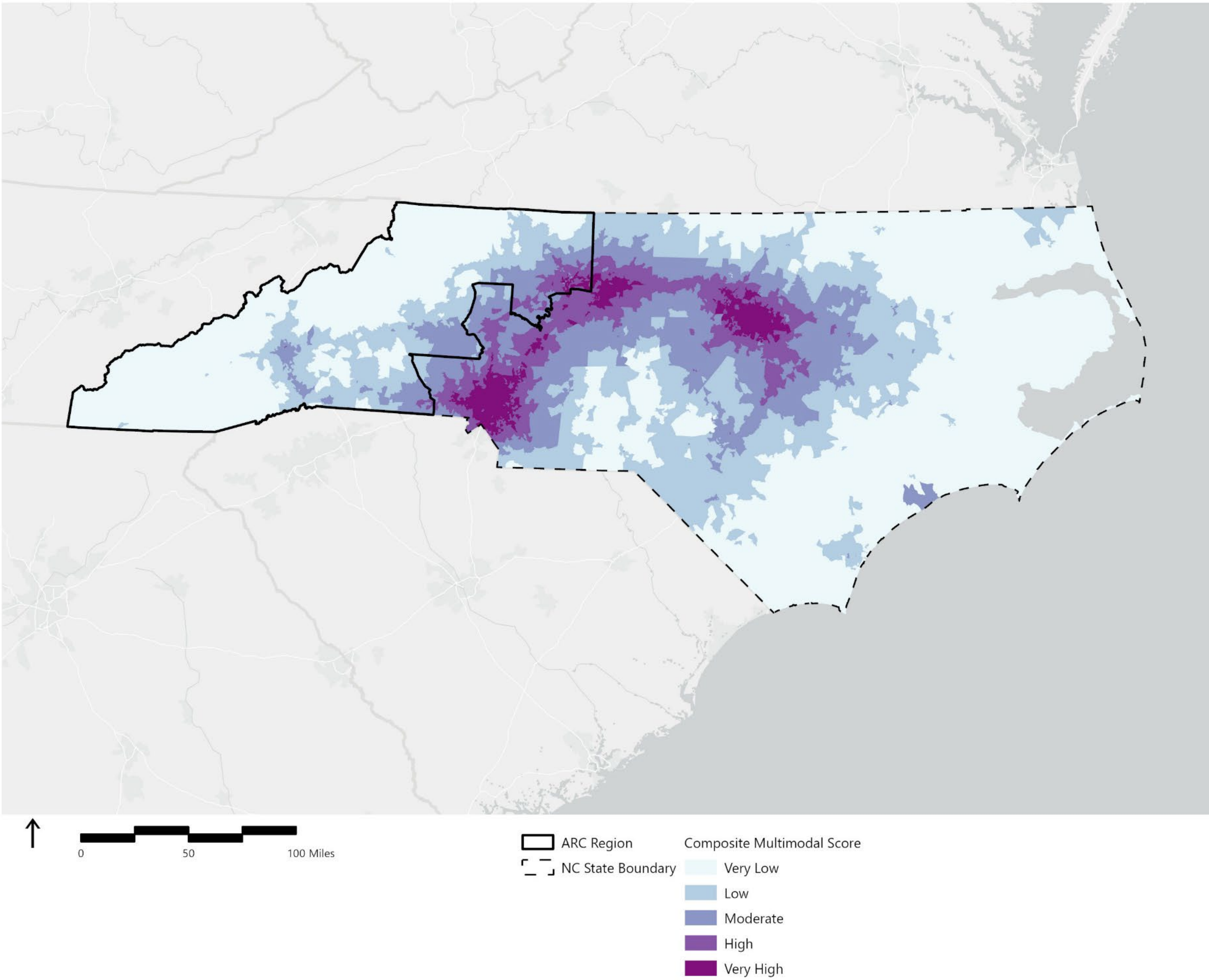


Figure 36. Composite Multimodal Access Score

## Application of Metrics

This chapter outlined four methods for assessing multimodal access across the state.

- **Direct Comparison by Destination Type:** This method allows NCDOT to directly compare driving and fixed route transit access by type of destination for a specific zone (i.e., block group). This provides a framework for comparing the need for transit service improvements relative to highway-specific improvements. Future iterations of this research could consider additional destination types and modes. The *Future Data Needs* chapter discusses some potential destinations for future analysis.
- **Categorical Access for Key Destinations:** This method provides discrete categories that can help NCDOT determine the diversity of access to essential services (healthcare as an example). Although the quality of access may vary slightly within each category, this method helps underscore where driving is essential, and options are limited. Future iterations of this research could consider additional destination types and modes.
- **Relative Comparison of Access Quality Statewide:** This Scorecard provides a relative comparison of access by mode in the state. As Table 14 illustrates, these scores can vary substantially by context within the state, and so this approach lends itself to both regional and statewide analysis of access.
- **Relative Comparison of Access for Communities:** This method focuses on access by modes most applicable to the needs of each zone. While the previous two methods do not consider potential need relative to the level of access in a zone, this method uses household vehicle availability to provide a weighted estimate of access for the community.

## Example Block Group Maps

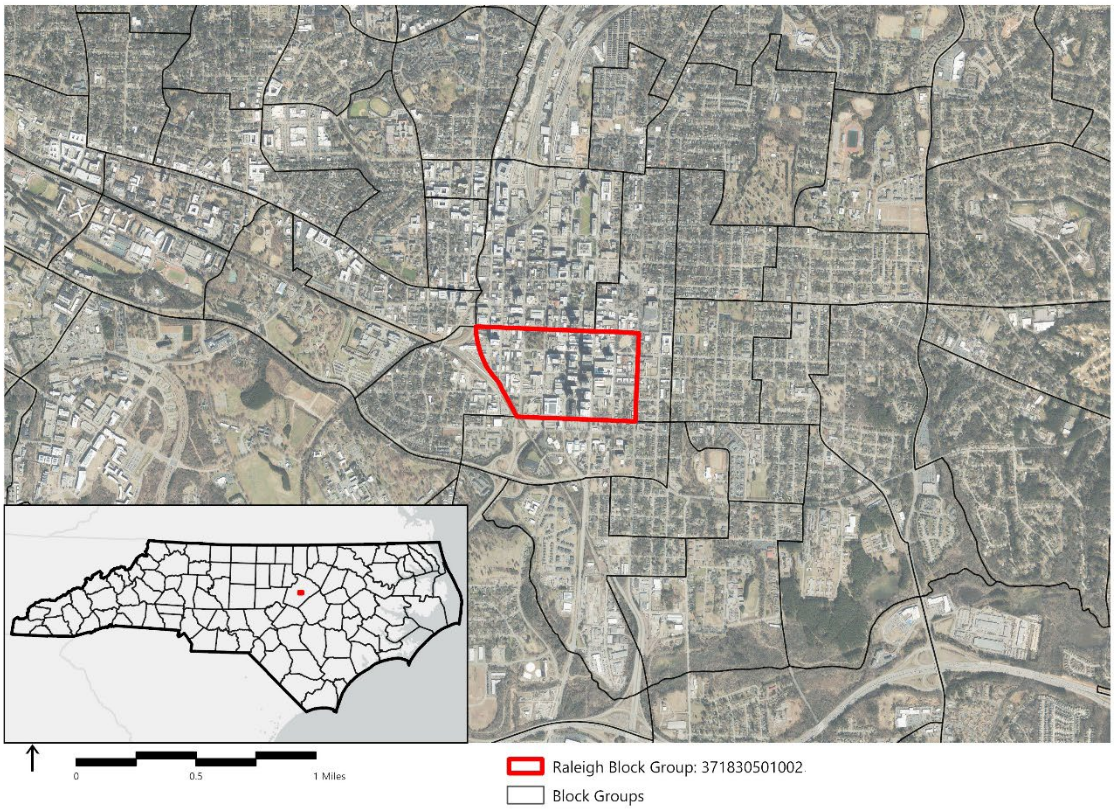


Figure 37. Downtown Raleigh - Block Group 501.02

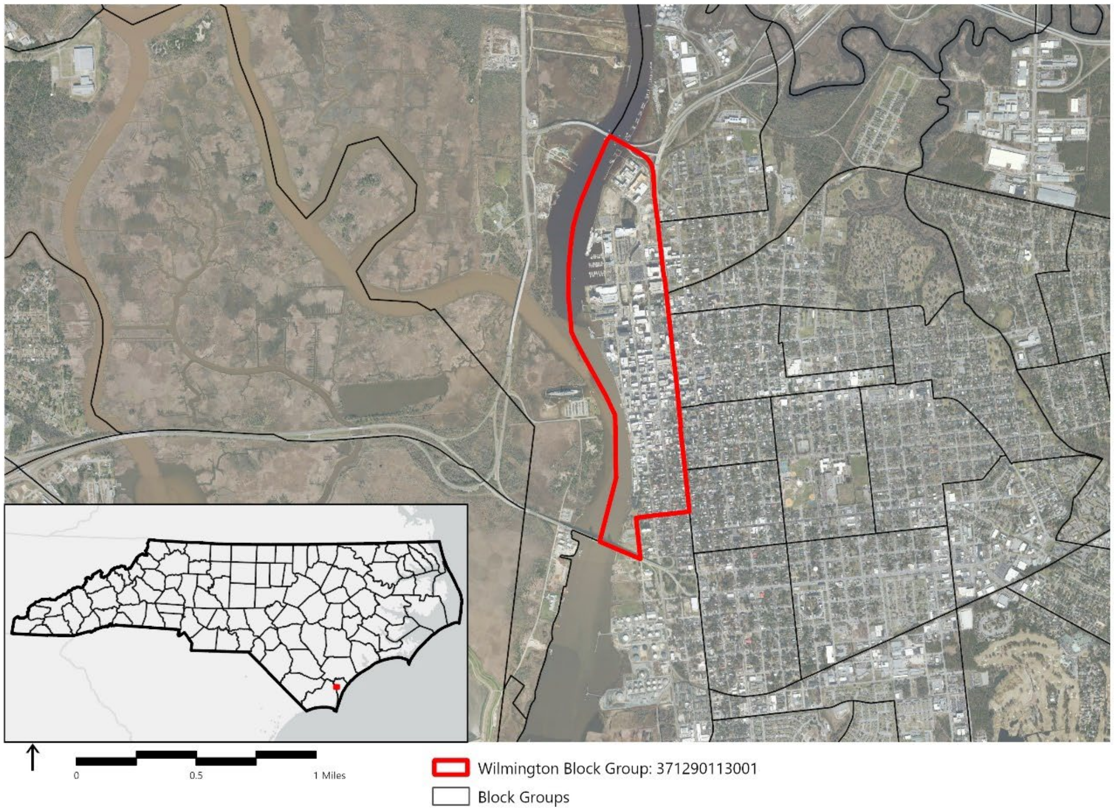


Figure 38. Downtown Wilmington - Block Group 113.01

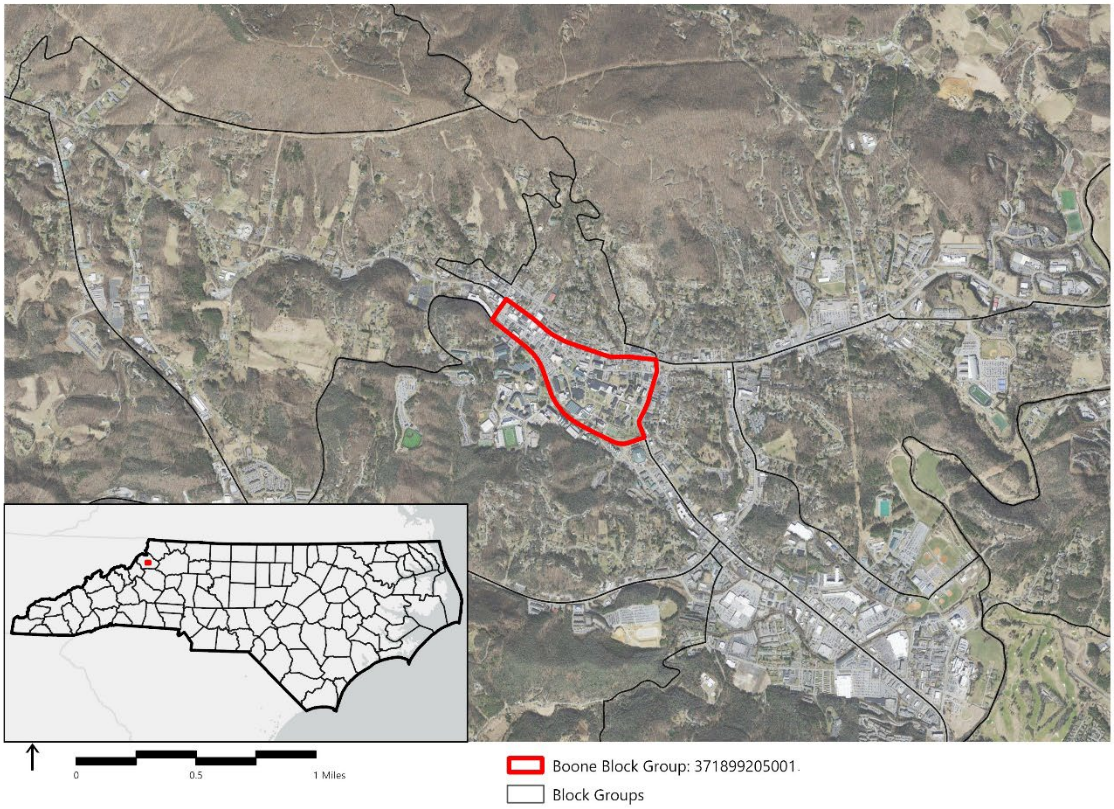


Figure 39. Downtown Boone - Block Group 9205.01

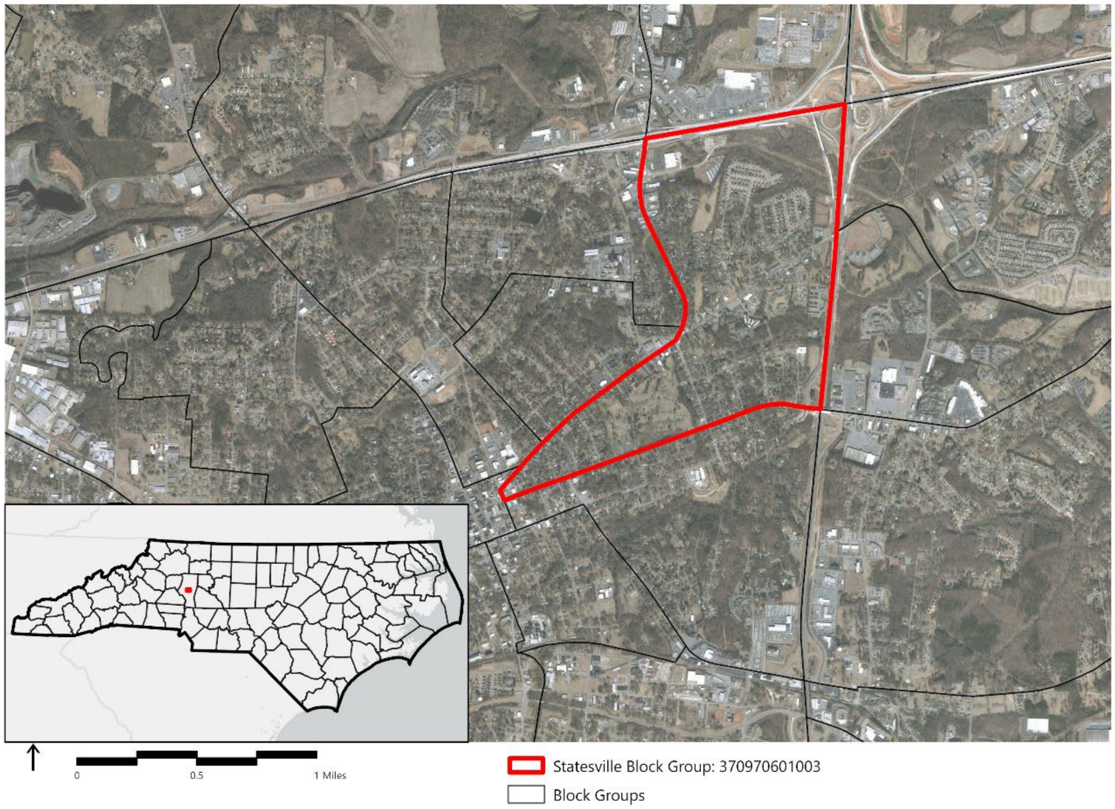


Figure 40. Statesville - Block Group 601.03

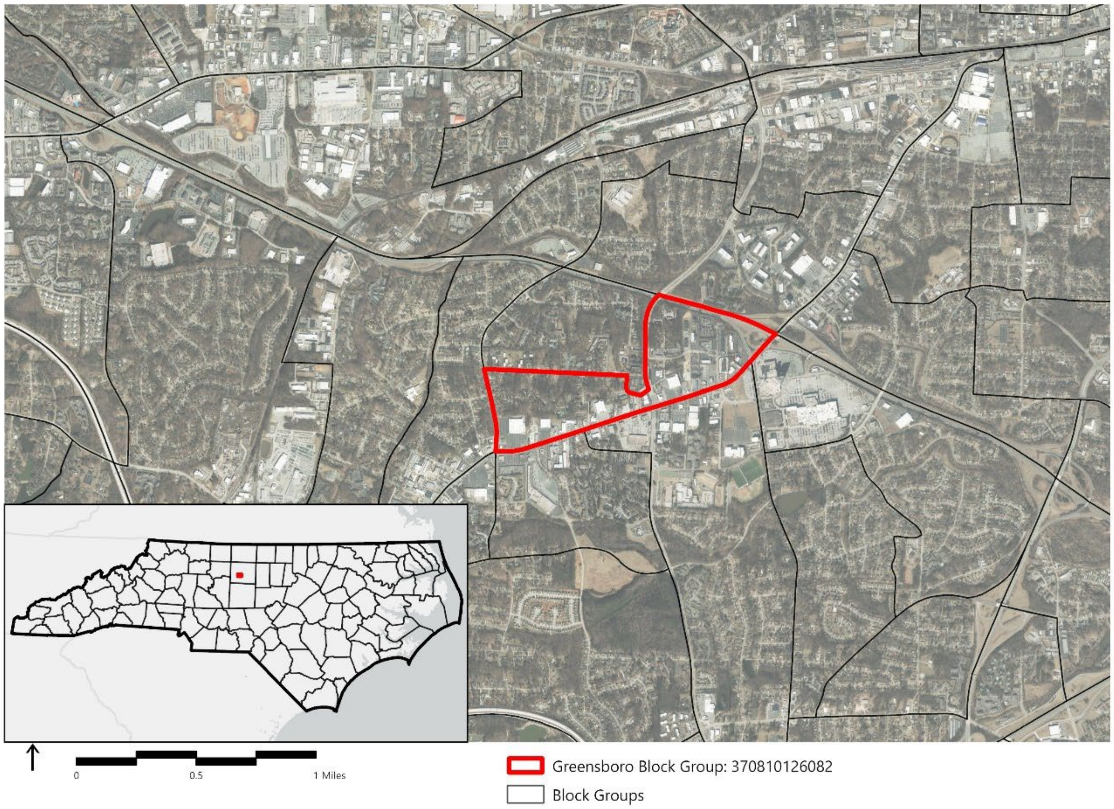


Figure 41. Greensboro - Block Group 126.08.2

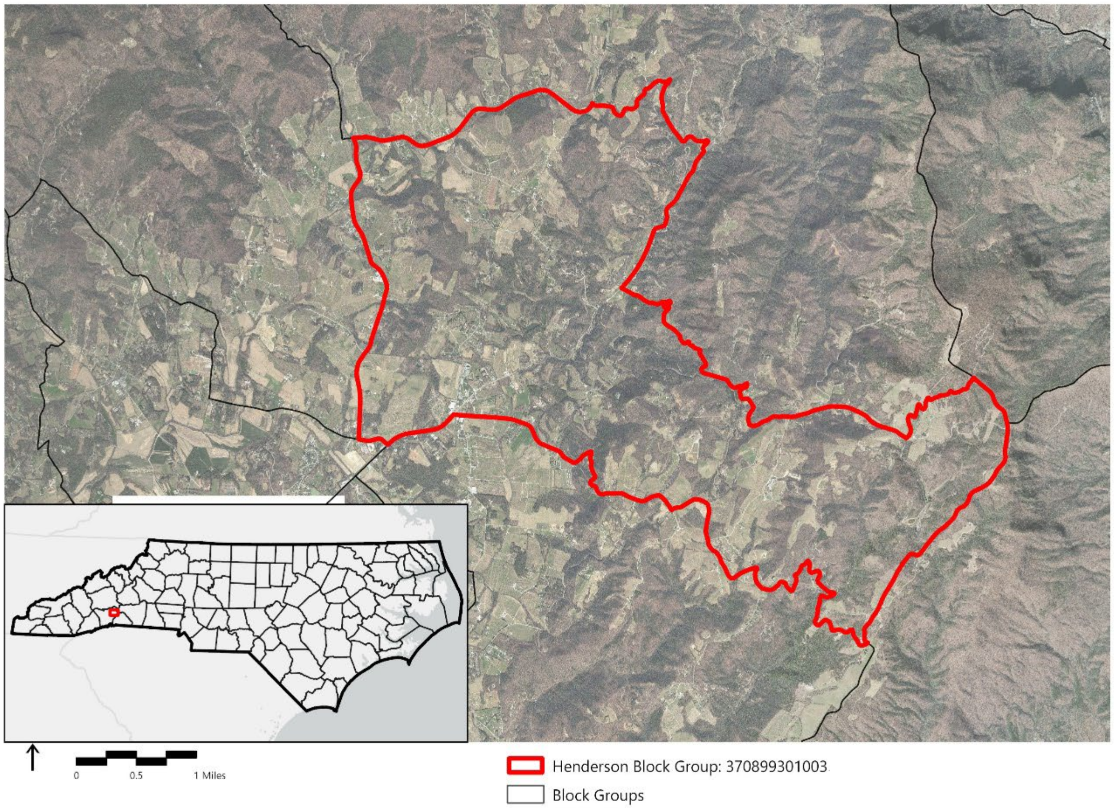


Figure 42. Henderson County - Block Group 9301.03

# 6

# Enhancing Multimodal Access & Key Findings

The final objective of the Access in Appalachia Pilot research was to outline ways in which access measures may support future transportation planning in North Carolina. The key findings of this research are based on the results of the existing conditions assessment in previous chapters, including the novel approaches to data and analysis that supported this assessment, as well as potential practical applications of the research in the future.

## Access and Need

This research provided a framework for contextualizing both access and need. Access considers how well infrastructure and network performance (i.e., typical NCDOT business functions) connect people to destinations. Need considers for whom is access particularly important. The communities where access is low and need is high should be a focus for future improvements. Furthermore, since this research conducted a statewide assessment, access and need can be considered across North Carolina as a whole or by:

- Urban/Rural context,
- Appalachian Region,
- NCDOT Division,
- Metropolitan or Rural planning organization (MPO or RPO),
- County, or
- Municipality.

## Geographic Scope and Study Area

This research incorporated destinations, demographics, and travel conditions beyond the state's borders to develop a more comprehensive assessment of access. This approach considered spillover effects and reduced uncertainty around state boundaries that are typically not considered in measures of statewide access and project impacts.

## Multimodal Scope and Policy Support

This research assessed five different travel modes using metrics that support potential policy decisions for each mode. For instance, drive time and fixed route transit access reflect travel time and level of service. For driving, reducing congestion and adding network linkages would improve access metrics, while for fixed route transit, additional stops, routes, and transfers, as well as more frequent service (in addition to reduced congestion and network linkages) would improve its access metrics. For demand response transit, biking, and walking, quality of service and the stress of the network is most important. Additional vehicles, more operating days, and more timely trip scheduling would improve demand response access metrics, while lower stress networks, additional sidewalk infrastructure, and better roadway connectivity would improve biking and walking access metrics.

## Equity and Impact on Specific Populations

Each mode, as well as the comparison between driving and non-driving, considered relevant communities and populations where improvements in access could be most profound. For instance, the opportunity metric for drive time for people considered TDI as an indicator where greater access is most needed. The non-driving modes, fixed route transit, demand response transit, biking, and walking, built upon this by emphasizing zero-vehicle households in addition to TDI. For drive time access to business, county-level economic distress metrics highlighted communities where business-oriented need for greater access is highest.

## Impacting Access and Opportunity in Project Programming

This research proposed four approaches for cross-modal comparison and assessing needs for multiple modes. These approaches generally fall within two categories: Direct Comparison and Relative Comparison:

- **Direct Comparison** compares driving and non-driving access in objective terms – how many more destinations can I access by one mode opposed to another, or can I reasonably access a destination with a particular mode?
- **Relative Comparison** compares the relative access of driving and non-driving – how accessible (i.e., easy) is it to reach destinations using a particular mode in my community relative to other communities in the state?

Each approach can be used to answer key questions about the transportation network and access in North Carolina, and ultimately support transportation planning decisions. For instance, urban communities tend to have greater access to amenities statewide. This is true for the Appalachian Region as well, although Appalachia in North Carolina as a whole tends to have lower relative access than peer locations elsewhere in the state (Figure 43).

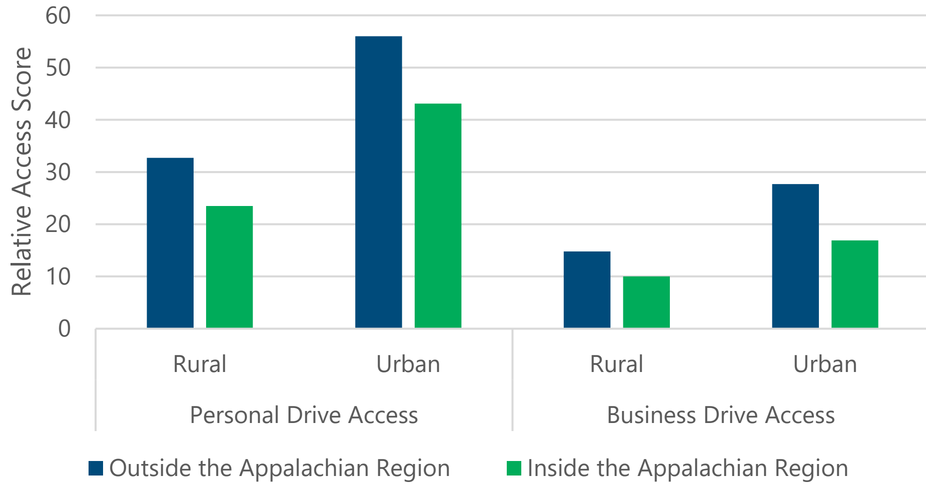


**Figure 43. Comparison of Average Personal and Business Drive Access Scores across Communities in North Carolina[22]**

Relative and direct comparisons need not be mutually exclusive as well. NCDOT could incorporate a relative and a direct comparison to assess the potential access benefits of a project. There are many project types and categories that would affect the modal metrics incorporated in this research, and thereby produce quantifiable impacts that would improve a block group's access. Furthermore, communities with the highest opportunity scores (i.e., low access and high need) represent potential priority locations for future multimodal investments.

Table 17 provides a summary of project and investment types by mode that could have quantifiable changes to the measures used in this research. For instance, additional mileage of sidewalk in a block group would increase the *Available Infrastructure* component of a block group's score. The list of potential improvements that could influence access can be expanded as additional modal data are incorporated in statewide scoring (see *Future Data* Needs chapter).

[22] Note that scores are not necessarily comparable between modes, and the figure should only be used to compare within a single mode.

**Table 17. Project Types and Outcomes that Could Impact Personal Multimodal Access**

| Fixed Route Transit | Demand Response Transit | Bicycle and Pedestrian |
|---|---|---|
| › Additional stops by key household destinations.<br>› More frequent headways to key destinations.<br>› Additional connections between adjacent transit services. | › Additional hours of service per day.<br>› Additional days of service per year.<br>› Additional vehicle seat hours per year.<br>› Additional connections between adjacent transit services.<br>› Provision of additional trip scheduling options.<br>› Establishing same day service. | › Additional sidewalk (or shared use path) connections.<br>› Road diets or lane reductions on arterials.<br>› Posted speed limit reductions (especially in coordination with other speed manage strategies).<br>› Increased roadway network connectivity (i.e., new road, trail, and greenway connections) and density of pedestrian-accessible intersections. |

# 7

# Future Data Needs

The purpose of this chapter is to outline key data limitations that informed the course of this research, as well as summarize a vision for future enhancements to the methods and data incorporated in this research. The data collected to support this research were obtained from several sources and do may reflect different points in time. For instance, documented connections between demand response agencies reflect a 2017 research study, while the OpStats data reflect the 2022 fiscal year. As NCDOT considers implementing the metrics and findings of this research, data should be actively reviewed and maintained to ensure the data are:

- **Accurate:** For instance, are destinations currently open to the public and operating.
- **Comprehensive:** For instance, are there significant gaps in portions of the state, such as missing bicycle and pedestrian linkages in rural areas or on non-DOT maintained roads.
- **Timely:** For instance, do GTFS files reflect the current operations of transit systems or have potential and observed connections between transit systems been recently inventoried.
- **Uniform:** For instance, are definitions of a CBD or a trauma center consistent across state boundaries. If definitions vary, are there consistent criteria for inclusion/exclusion of new destinations.

## Potential Recommendations

The following recommendations pertain to data available at the time of the research. NCDOT can consider these gaps when planning future data collection efforts. Furthermore, if regional planning agencies or municipalities had access to more detailed data, these agencies could apply the methods in this pilot research to produce more refined results.

### Missing or Limited Datasets

- Data that specifically delineate CBDs throughout the state would support more refined estimates of access to amenities that downtowns and commercial districts can provide.
- Data on primary care physicians for both North Carolina and surrounding states were not available at the time of the research, limiting the ability of the research to analyze access to healthcare across all metrics.
- NCDOT's Advancing Transportation through Linkages, Automation, and Screening (ATLAS) project has data on points of interest for several popular destination types, including places of worship,

tourism destinations, and medical centers. However, these data are not curated in detail, and many points of interest may not reflect desirable destinations. For instance:

- Park locations are a combination of active park space and more passive public land (e.g., National Parks and Forests). These locations function differently as recreation destinations and would likely need to be stratified for analysis.
- Medical center data encompass hospitals, urgent care centers, passive rehabilitation centers, non-profits, and research institutions without a concise metadata to distinguish destination subtypes. This bundling of data limit the insight on medical accessibility in the state in its current form.

By contrast, the research incorporated a more recently curated data layer that included grocery stores and locations that accept Supplemental Nutrition Assistance Program (SNAP) benefits. These were not a part of the formal SPOT 7.0 database, but they could be future addition to prioritization data.

## Routable Networks and Typical Study Conditions

The research relied on ESRI's proprietary roadway network and associated speed, volume, and congestion records to analyze access to business locations and household destinations via driving. The lack of comprehensively available speed limit data from NCDOT's Route Arcs and Route Characteristics files limited the ability of the research to build a custom, more open-source roadway network and model travel along the state's roadway system. This concern also extended to surrounding states, where speed limit data was limited to state-maintained roads in most contexts. Having a complete roadway characteristics file would enable the project team to build a more customizable model that could be edited regularly instead of relying on ESRI's roadway network and the additional costs associated with utilizing the pre-built network.

## Transit Data Reliability

### Fixed Route Transit

Fixed route GTFS data were only available for large transit providers in the state at the initiation of the research. These data change frequently (i.e., as services alter stop locations, routes, and headways), and therefore these data only represent a snapshot in time. Furthermore, many of the state's deviated fixed route services had no GIS or GTFS data readily available; these had to be manually coded and collated. This study built GTFS files for all fixed route transit systems that did not have one readily available based on PDF schedules published on each provider's webpage. An actively maintained repository of updated GTFS for all fixed-transit routes is recommended for future iterations of this research. The Transit Cooperative Research Program's (TCRP's) *Synthesis Report 172: Statewide Approaches to the Development of Comprehensive Transit Information Systems* provides insight into current data coordination practices (TCRP, 2023). Such a repository may also line up well with new GTFS reporting requirements in the National Transit Database.

### GTFS-Flex

GTFS data has also been limited to fixed route operation, limiting the ability for deviated fixed route, microtransit, and on-demand transit, to be modeled in a similar fashion. Incorporating GTFS-Flex into these provider's data networks would allow for modeling and incorporation of these transit options into public facing interfaces. GTFS-Flex would allow for additional information such as locations, service areas, stop areas, and booking rules into a GTFS format that could then be incorporated into the larger fixed route GTFS schema. Akin to standard GTFS, the GTFS-Flex would need to be updated on a regular basis for any service changes. As of the publication of this report, GTFS-Flex adoption is still far less wide-spread than traditional GTFS.

### Demand Response and Microtransit

Much of the data necessary for an initial assessment of demand response services in North Carolina was available to the research team. However, data availability at an agency level could be unreliable, and some gaps included:

- Operations data (i.e., OpStats) were missing for Forsyth County.
- Missing or anomalous beginning and ending operating hour times (e.g., 7 am to 8 am).
- Wilson County and Wilson City service consolidation - Wilson County and Wilson City had operated as a combined service from 2017 to 2021 but are now two separate agencies. Due to a lack of recent data to treat them separately, the project team continued to analyze them as a combined agency for the entire Wilson County.
- Inconsistencies between agency survey responses and NTD data.
- Missing data for Annual Operating Days.

Furthermore, scoring for demand response metrics differs significantly from other modes in the research as four out of the six metrics are relative to peer group performance (i.e., as opposed to statewide comparison). The research team, in consultation with NCDOT and ITRE, determined that this was the most appropriate approach at this time, although NCDOT may want to consider more normative, statewide thresholds for assessing accessibility as demand response service evolves in North Carolina.

The team also reviewed existing practices in performance measurement for Demand Response transit and noted that missed and denied trip rates are another metric used to capture service quality and the ability of supply to meet demand. No data on this was available during the study, but these types of metrics may merit consideration for future data collection.

Microtransit data were limited in North Carolina due to the service type's novelty in the state. As microtransit becomes a more widespread transit option, additional data metrics will be required to analyze access via all modes of transit:

- Polygons for transit zones
- Estimated wait time
- Pricing schema
- Pick-up request types
- Pick-up and drop-off locations and types
- Operating hours

## Vulnerable Road User Data Reliability

### Roadway Conditions

This research used simplified assumptions to determine ease of access and levels of stress for vulnerable road users (VRUs) based on NCDOT's Roadway Characteristics file. Like the caveats in the *Routable Networks and Typical Study Conditions* section, addressing missing speed limits, lane counts, and median type/widths can also improve accessibility metrics related to VRUs.

### Infrastructure

The reliability of NCDOT's Pedestrian Bicycle Infrastructure Network (PBIN) varies significantly by jurisdiction (e.g., urban/rural or within municipal boundaries) and type of dataset (e.g., crosswalk or sidewalk). Although NCDOT's ATLAS project actively maintains the data in piecemeal improvements, the PBIN is most accurate in larger urban areas who have the staff to update their data and submit it to NCDOT. Smaller suburban and rural communities, who often do not have staff versed in GIS or the resources to maintain these data have limited PBIN data available; data that are available can be frequently outdated or contradictory to past submittals.

Machine learning (ML) applications provide the potential to improve many datasets related to bicycle and pedestrian infrastructure. Open-source model packages, including Convolutional Neural Networks (CNNs) and You Only Look Once (YOLO) for feature detection and Support Vector Machines (SVMs) and Random Forests for image classification, can be trained on aerial or street-level imagery to detect key features. To support key elements of this research, NCDOT could consider more robust inventories of the following:

- Marked crosswalks
- Sidewalks
- Sidepaths
- Midblock crossings, including:
    - Median refuges
    - Pedestrian hybrid beacons (PHBs)
    - Rapid rectangular flashing beacons (RRFBs)

Furthermore, recreational access was not directly considered in this research (i.e., trips with no fixed or dependent destination). If NCDOT modified future applications to consider recreation-based travel, trail and greenway connections may need to be collected and reviewed for accuracy.

### Exposure

Although not an objective of this research, more comprehensive and robust data regarding pedestrian and bicyclist volumes could contribute to refining the metrics used to determine VRU access. FHWA's *An Exploration of Pedestrian Safety Through the Integration of HSIS and Emerging Data Sources: Case Study in Charlotte, NC* (Hamilton et al., 2021) and NCDOT's *Quantification of Systemic Risk Factors for Pedestrian Safety on North Carolina* (Gayah et al., 2022) explored applications of pedestrian exposure statistical models in urban areas; the NCDOT research determined that specific estimates may be unreliable, but the magnitude of estimates, as well as the contributing factors in the exposure models, could help inform location-specific estimates of these users. This approach, supplemented with additional count data provided by an expanded Non-Motorized Volume Data Program (NMVDP) or location-based services (LBS) dataset vetted and obtained by NCDOT, can help refine thresholds of road characteristics (e.g., traffic volumes and speed) that may pose barriers to access.

### Modal Connections not Captured in the Research

The research did not consider accessibility via aviation, passenger or freight rail, or ferry system. Although these are modes considered in the state's SPOT prioritization program, these modes had limited geographic applicability and daily utility that limited the potential impact on research outcomes; however, these data would be necessary for a wholly comprehensive assessment accessibility statewide. Additionally, provision of air and freight rail service is typically the purview of the private sector and therefore influenced by not directly provided by NCDOT and its government partners.

### Post COVID-19 Changes

This research generally captured data prior to stay-at-home conditions as a result of the COVID-19 pandemic. Future iterations of the research may want to revisit typical travel thresholds reported in surveys (i.e., the distance people are willing to travel by mode), inputs to Census survey data, and other transportation dynamics (e.g., remote work) that could influence relevant access metrics.

## Summary of Potential Recommendations by Mode

Table 18 provides a summary of the gaps and potential improvements in relation to the applicable modal analyses that could be improved. Items with a checkmark indicate how additional information in column one may impact accessibility metric scoring for mode type in the following columns.

Table 18. Summary of Potential Recommendations by Impacted Mode

| Potential Improvement | Drive Access | Fixed Route Transit | Demand Response Transit | Bicycle and Pedestrian | Business Drive Access |
|---|---|---|---|---|---|
| **Detailed Central Business Districts** | ✓ | ✓ | ✓ | ✓ | |
| **Primary Care Physician Location** | ✓ | ✓ | ✓ | ✓ | |
| **Refined SPOT Points of Interest Data** | ✓ | ✓ | ✓ | ✓ | |
| **Missing Route Characteristics** | ✓ | | | ✓ | ✓ |
| **Surrounding State Speed Data** | ✓ | | | | ✓ |
| **Statewide Fixed Route Transit GTFS Repository** | | ✓ | | | |
| **Supplementary OpStats Data** | | | ✓ | | |
| **Microtransit Metrics and Data** | | | ✓ | | |
| **PBIN Refinements and Supplementary Data** | | ✓ | | ✓ | |
| **Bicycle and Pedestrian Exposure** | | ✓ | | ✓ | |
| **Additional Modal Connections** (including Passenger Rail and Ferry Routes) | ✓ | ✓ | ✓ | ✓ | ✓ |

# A-1

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# A-2

## Definition of a Demand Response Connection

The following are potential connection types for community transportation (i.e., demand response) systems (ITRE, 2017; p. 17-18):

**"Expected System Connections**: All community transportation, urban, regional, and intercity transit service providers located inside the 10-mile connection area buffer were counted as an expected connection ($Z_e$). Transit systems outside the connection area were not counted.

Transit system categories influenced the definition and measure of an expected connection:

**Community Transportation Systems**

- Any bordering system that has contiguous jurisdictional boundaries and has a state road connecting the two jurisdictions is an expected community transportation connection.
- As established by NCDOT practice, a ferry route was considered a state road and was counted as such for this analysis. This was relevant for services connecting Dare to Hyde, Hyde to Carteret, and New Hanover to Brunswick.

**Hybrid Urban and Community Transportation Systems**

- For combined Urban/community transportation systems, those with an urban stop insider the 10-mile connection area were scored as an expected urban connection. If the bordering consolidated system (e.g. Tar River Transit) is contiguous and the urban route falls outside the connection area, it was scored as an expected community transportation connection. Connections between the community transportation and urban service of the same transit system are not considered in the formula because these are not external connections.

**Intercity Transit Systems**

There are two types of intercity transit connections:

- *Internal*: Stops that fall within the community transportation system's jurisdictional boundaries. A community transportation system is expected to service every internal Amtrak and Intercity Bus stop.
- *External*: Stops that fall outside the community transportation system's jurisdictional boundaries but within a 10-mile buffer. A community transportation system is not expected to service an external Amtrak or ICB stop if that mode has an internal presence. If a community transportation system has no internal stops and multiple external stops of the same mode, it is only expected to

service one of the external stops. Where the transit system services multiple external stops, as in the case with Rowan, the expected number is increased to match the observed so that the connectivity score does not exceed 1.0.

**Observed System Connections**: Unlike the urban system scoring method that uses GTFS data, the community transit system scoring method relied on primary data collection obtained from each community transportation system's website. Websites were used in lieu of contacting the community transportation systems because valid connections should have publicly accessible route location and time information to be considered as a true connection; this same logic supports the requirement of a GTFS file for urban systems.

The measure of an observed transit system connection relies on a number of components related to other community transportation systems, urban systems, regional systems, and intercity transit systems:

- **Public Awareness**: Publicly available schedules and maps posted on the system's website.
- **Fixed Routes**: Any fixed route that connects with a fixed route of another system (both urban and rural) was counted as a connection.
- **Demand Response**: An actual connection may be carried out through a fixed route, deviated fixed route, or demand response service.

**Observed – But Not Expected – System Connections:** In some circumstances a transit service provider may have an observed connection with other transit systems that are *not* expected to connect with. In these circumstances, the unexpected connection is added to both the expected $(Z_e + 1)$ and observed $(Z_o + 1)$ transit system connection categories to ensure that the score cannot exceed a value of 1 (observed $(Z_o)$/expected$(Z_e)$)."

# A-3

## Community Survey Template

The North Carolina Department of Transportation (NCDOT) is researching disparities across transportation modes in access to jobs, education, healthcare, and other essential services. As part of this effort, NCDOT is interested in accessibility to demand response transit, particularly with respect to variability in service area and trip reservation policies. This survey should take approximately 5-10 minutes to complete. Your response is critical assessing access across the state for those with the highest need, and it will be essential for project decisions in future funding cycles.

1. **Service Area**
    a. Does the service extend outside of the base service area for any reason?
        i. Yes.
        ii. No.
    b. Does your service area vary by time of day, day of week, or some other criteria?
        i. Yes.
        ii. No.

    *If yes to b, then ask c and d:*

    c. How does the **service area** change based on the day of the week (e.g., weekday, weekend, holiday)? In other words, does the geographic extent of service vary by the day of the week?
    d. How does the **service area** change based on time of day (e.g., morning, afternoon, evening)?
2. **Trip Scheduling Policy**
    a. How does a rider request a pick-up (select all that apply)?
        i. Website.
        ii. App.
        iii. Phone-call.
        iv. Referral (medical or social service).
        v. In-person.
        vi. Third-party provider.
    b. What is the minimum lead time required to make a trip reservation (i.e., the latest a rider can make a request prior to the trip and have the reservation accepted) for the general public during a **typical week**?
        i. None (totally on demand).
        ii. 1 Hour or less.

    iii. Same day.
    iv. More than 24 hours in advance.
    v. Service is not available for this time.

c. What is the minimum lead time required to make a trip reservation for the general public during a **typical weekend**?
    i. None (totally on demand).
    ii. 1 Hour or less.
    iii. Same day.
    iv. More than 24 hours in advance.
    v. Service is not available for this time.
d. What is minimum lead time required to make a trip reservation for the general public during a **typical holiday**?
    i. None (totally on demand).
    ii. 1 Hour or less.
    iii. Same day.
    iv. More than 24 hours in advance.
    v. Service is not available for this time.
e. What is the minimum lead time required to make a trip reservation for agency-sponsored trips during a **typical week**?
    i. None (totally on demand).
    ii. 1 Hour or less.
    iii. Same day.
    iv. More than 24 hours in advance.
    v. Service is not available for this time.
f. What is the minimum lead time required to make a trip reservation for agency-sponsored trips during a **typical weekend**?
    i. None (totally on demand).
    ii. 1 Hour or less.
    iii. Same day.
    iv. More than 24 hours in advance.
    v. Service is not available for this time.
g. What is the minimum lead time required to make a trip reservation for agency-sponsored trips during a **typical holiday**?
    i. None (totally on demand).
    ii. 1 Hour or less.
    iii. Same day.
    iv. More than 24 hours in advance.
    v. Service is not available for this time.

# A-4

## Categorical Access by Tier and County

Table 19. Total and Percent of County Population in Example Categorical Tiers of Access to Essential Healthcare[23]

| County | Total Tier 1 | Total Tier 2 | Total Tier 3 | Total County | Percent Tier 1 | Percent Tier 2 | Percent Tier 3 |
|---|---|---|---|---|---|---|---|
| New Hanover | 30,071 | 119,530 | 78,537 | 228,138 | 13.2% | 52.4% | 34.4% |
| Person | 4,754 | 7,655 | 28,050 | 40,459 | 11.8% | 18.9% | 69.3% |
| Orange | 16,834 | 86,411 | 42,672 | 145,917 | 11.5% | 59.2% | 29.2% |
| Pitt | 18,610 | 61,128 | 92,891 | 172,629 | 10.8% | 35.4% | 53.8% |
| Guilford | 50,401 | 281,321 | 211,336 | 543,058 | 9.3% | 51.8% | 38.9% |
| Durham | 29,926 | 197,111 | 98,710 | 325,747 | 9.2% | 60.5% | 30.3% |
| Mecklenburg | 101,845 | 726,618 | 286,682 | 1,115,145 | 9.1% | 65.2% | 25.7% |
| Cumberland | 30,423 | 128,861 | 176,410 | 335,694 | 9.1% | 38.4% | 52.6% |
| Forsyth* | 32,274 | 167,522 | 183,939 | 383,735 | 8.4% | 43.7% | 47.9% |
| Rowan | 12,362 | 30,485 | 106,026 | 148,873 | 8.3% | 20.5% | 71.2% |
| Catawba* | 10,228 | 52,185 | 98,585 | 160,998 | 6.4% | 32.4% | 61.2% |
| Wake | 71,620 | 581,243 | 484,192 | 1,137,055 | 6.3% | 51.1% | 42.6% |
| Craven | 5,674 | 17,376 | 78,031 | 101,081 | 5.6% | 17.2% | 77.2% |
| Rockingham | 4,447 | 33,512 | 53,252 | 91,211 | 4.9% | 36.7% | 58.4% |
| Buncombe* | 12,920 | 153,259 | 103,236 | 269,415 | 4.8% | 56.9% | 38.3% |
| Alamance | 7,800 | 65,177 | 98,799 | 171,776 | 4.5% | 37.9% | 57.5% |
| Wayne | 5,208 | 30,185 | 82,076 | 117,469 | 4.4% | 25.7% | 69.9% |
| Henderson* | 4,964 | 40,259 | 71,225 | 116,448 | 4.3% | 34.6% | 61.2% |
| Cabarrus | 9,395 | 81,969 | 135,313 | 226,677 | 4.1% | 36.2% | 59.7% |
| Randolph | 5,852 | 11,683 | 128,397 | 145,932 | 4.0% | 8.0% | 88.0% |
| Watauga* | 2,127 | 28,554 | 23,859 | 54,540 | 3.9% | 52.4% | 43.7% |
| Onslow | 7,420 | 55,245 | 141,002 | 203,667 | 3.6% | 27.1% | 69.2% |
| Iredell | 6,060 | 40,097 | 141,708 | 187,865 | 3.2% | 21.3% | 75.4% |
| Cleveland* | 3,176 | 19,038 | 77,303 | 99,517 | 3.2% | 19.1% | 77.7% |
| Davidson | 4,779 | 37,577 | 127,137 | 169,493 | 2.8% | 22.2% | 75.0% |
| Macon* | 978 | 4,969 | 31,136 | 37,083 | 2.6% | 13.4% | 84.0% |
| Haywood* | 1,602 | 4,744 | 55,796 | 62,142 | 2.6% | 7.6% | 89.8% |
| Scotland | 723 | 14,404 | 19,093 | 34,220 | 2.1% | 42.1% | 55.8% |
| Brunswick | 2,712 | 26,422 | 110,599 | 139,733 | 1.9% | 18.9% | 79.2% |

[23] Asterisk refers to an Appalachian Region County

| County | Total Tier 1 | Total Tier 2 | Total Tier 3 | Total County | Percent Tier 1 | Percent Tier 2 | Percent Tier 3 |
|---|---|---|---|---|---|---|---|
| Surry* | 1,334 | 8,764 | 61,335 | 71,433 | 1.9% | 12.3% | 85.9% |
| Moore | 1,726 | 13,596 | 85,627 | 100,949 | 1.7% | 13.5% | 84.8% |
| Nash | 1,537 | 37,548 | 55,929 | 95,014 | 1.6% | 39.5% | 58.9% |
| Rutherford* | 834 | 16,617 | 47,224 | 64,675 | 1.3% | 25.7% | 73.0% |
| Wilkes* | 832 | 10,952 | 54,341 | 66,125 | 1.3% | 16.6% | 82.2% |
| Gaston | 2,826 | 63,477 | 162,781 | 229,084 | 1.2% | 27.7% | 71.1% |
| Union | 2,932 | 5,009 | 233,686 | 241,627 | 1.2% | 2.1% | 96.7% |
| Jackson* | 503 | 8,881 | 32,997 | 42,381 | 1.2% | 21.0% | 77.9% |
| Ashe* | 250 | 8,222 | 18,414 | 26,886 | 0.9% | 30.6% | 68.5% |
| Davie* | 283 | 11,933 | 30,812 | 43,028 | 0.7% | 27.7% | 71.6% |
| Burke* | 467 | 22,817 | 64,510 | 87,794 | 0.5% | 26.0% | 73.5% |
| Vance | 147 | 14,353 | 27,993 | 42,493 | 0.3% | 33.8% | 65.9% |
| Cherokee* | 88 | 4,635 | 24,143 | 28,866 | 0.3% | 16.1% | 83.6% |
| Alexander* | 0 | 9,657 | 26,848 | 36,505 | 0.0% | 26.5% | 73.5% |
| Alleghany* | 0 | 114 | 10,875 | 10,989 | 0.0% | 1.0% | 99.0% |
| Anson | 0 | 50 | 22,148 | 22,198 | 0.0% | 0.2% | 99.8% |
| Avery* | 0 | 94 | 17,585 | 17,679 | 0.0% | 0.5% | 99.5% |
| Beaufort | 0 | 2,858 | 41,848 | 44,706 | 0.0% | 6.4% | 93.6% |
| Bertie | 0 | 86 | 17,732 | 17,818 | 0.0% | 0.5% | 99.5% |
| Bladen | 0 | 1,093 | 28,712 | 29,805 | 0.0% | 3.7% | 96.3% |
| Caldwell* | 0 | 5,462 | 75,252 | 80,714 | 0.0% | 6.8% | 93.2% |
| Camden | 0 | 0 | 10,548 | 10,548 | 0.0% | 0.0% | 100.0% |
| Carteret | 0 | 3,318 | 65,032 | 68,350 | 0.0% | 4.9% | 95.1% |
| Caswell | 0 | 0 | 22,748 | 22,748 | 0.0% | 0.0% | 100.0% |
| Chatham | 0 | 2,416 | 74,336 | 76,752 | 0.0% | 3.1% | 96.9% |
| Chowan | 0 | 1,366 | 12,469 | 13,835 | 0.0% | 9.9% | 90.1% |
| Clay* | 0 | 0 | 11,185 | 11,185 | 0.0% | 0.0% | 100.0% |
| Columbus | 0 | 1,832 | 48,995 | 50,827 | 0.0% | 3.6% | 96.4% |
| Currituck | 0 | 0 | 28,619 | 28,619 | 0.0% | 0.0% | 100.0% |
| Dare | 0 | 174 | 36,985 | 37,159 | 0.0% | 0.5% | 99.5% |
| Duplin | 0 | 891 | 48,420 | 49,311 | 0.0% | 1.8% | 98.2% |
| Edgecombe | 0 | 14,273 | 34,794 | 49,067 | 0.0% | 29.1% | 70.9% |
| Franklin | 0 | 0 | 69,680 | 69,680 | 0.0% | 0.0% | 100.0% |
| Gates | 0 | 0 | 10,509 | 10,509 | 0.0% | 0.0% | 100.0% |
| Graham* | 0 | 0 | 8,047 | 8,047 | 0.0% | 0.0% | 100.0% |
| Granville | 0 | 940 | 60,224 | 61,164 | 0.0% | 1.5% | 98.5% |
| Greene | 0 | 0 | 20,406 | 20,406 | 0.0% | 0.0% | 100.0% |
| Halifax | 0 | 2,717 | 46,056 | 48,773 | 0.0% | 5.6% | 94.4% |
| Harnett | 0 | 5,502 | 129,185 | 134,687 | 0.0% | 4.1% | 95.9% |
| Hertford | 0 | 683 | 20,950 | 21,633 | 0.0% | 3.2% | 96.8% |
| Hoke | 0 | 1,793 | 50,812 | 52,605 | 0.0% | 3.4% | 96.6% |
| Hyde | 0 | 0 | 4,636 | 4,636 | 0.0% | 0.0% | 100.0% |
| Johnston | 0 | 5,748 | 213,271 | 219,019 | 0.0% | 2.6% | 97.4% |
| Jones | 0 | 0 | 9,263 | 9,263 | 0.0% | 0.0% | 100.0% |

| County | Total Tier 1 | Total Tier 2 | Total Tier 3 | Total County | Percent Tier 1 | Percent Tier 2 | Percent Tier 3 |
|---|---|---|---|---|---|---|---|
| Lee | 0 | 4,988 | 58,562 | 63,550 | 0.0% | 7.8% | 92.2% |
| Lenoir | 0 | 2,271 | 52,794 | 55,065 | 0.0% | 4.1% | 95.9% |
| Lincoln | 0 | 3,169 | 84,751 | 87,920 | 0.0% | 3.6% | 96.4% |
| Madison* | 0 | 0 | 21,414 | 21,414 | 0.0% | 0.0% | 100.0% |
| Martin | 0 | 407 | 21,583 | 21,990 | 0.0% | 1.9% | 98.1% |
| McDowell* | 0 | 532 | 44,094 | 44,626 | 0.0% | 1.2% | 98.8% |
| Mitchell* | 0 | 243 | 14,745 | 14,988 | 0.0% | 1.6% | 98.4% |
| Montgomery | 0 | 118 | 25,718 | 25,836 | 0.0% | 0.5% | 99.5% |
| Northampton | 0 | 0 | 17,528 | 17,528 | 0.0% | 0.0% | 100.0% |
| Pamlico | 0 | 71 | 12,245 | 12,316 | 0.0% | 0.6% | 99.4% |
| Pasquotank | 0 | 1,535 | 38,918 | 40,453 | 0.0% | 3.8% | 96.2% |
| Pender | 0 | 1,470 | 60,121 | 61,591 | 0.0% | 2.4% | 97.6% |
| Perquimans | 0 | 0 | 13,053 | 13,053 | 0.0% | 0.0% | 100.0% |
| Polk* | 0 | 609 | 18,925 | 19,534 | 0.0% | 3.1% | 96.9% |
| Richmond | 0 | 1,372 | 41,775 | 43,147 | 0.0% | 3.2% | 96.8% |
| Robeson | 0 | 6,698 | 110,871 | 117,569 | 0.0% | 5.7% | 94.3% |
| Sampson | 0 | 2,963 | 56,350 | 59,313 | 0.0% | 5.0% | 95.0% |
| Stanly | 0 | 1,979 | 60,738 | 62,717 | 0.0% | 3.2% | 96.8% |
| Stokes* | 0 | 20 | 44,676 | 44,696 | 0.0% | 0.0% | 100.0% |
| Swain* | 0 | 2,583 | 11,544 | 14,127 | 0.0% | 18.3% | 81.7% |
| Transylvania* | 0 | 641 | 32,485 | 33,126 | 0.0% | 1.9% | 98.1% |
| Tyrrell | 0 | 0 | 3,389 | 3,389 | 0.0% | 0.0% | 100.0% |
| Warren | 0 | 0 | 18,803 | 18,803 | 0.0% | 0.0% | 100.0% |
| Washington | 0 | 189 | 10,862 | 11,051 | 0.0% | 1.7% | 98.3% |
| Wilson | 0 | 5,538 | 73,123 | 78,661 | 0.0% | 7.0% | 93.0% |
| Yadkin* | 0 | 0 | 37,280 | 37,280 | 0.0% | 0.0% | 100.0% |
| Yancey* | 0 | 0 | 18,538 | 18,538 | 0.0% | 0.0% | 100.0% |

# A-5

# GTFS Template

## Schedule Template Rules

- One Sheet for each unique Route, Direction, and Day Type (ex. Rt 1 Weekdays EAST and Rr 1 Weekdays WEST would require 2 separate sheets. Additional 1 Weekdays EAST Saturday would require a third sheet, etc.).
- Anything that has “Id” in it cannot have spaces or special characters.
- Operating Day: Acceptable Entries include: “Weekdays”, “Weekends”, “Monday”,“Mon”,“mon”,etc. Can also include multiple days such as: “Monday, Wednesday, Friday”.
- Direction: Acceptable entries are only 0 (for outbound) or 1 (for inbound). For the project moving forward, we may need to make a verdict on this to be consistent across all systems (ex. all North and West are 1 and all East and South are 0).
- Trip_Id: Each column **MUST** be unique. No trips even on separate routes, days, or directions, can have the same ID.
- Stop Id: Reference stop shapefile for stop_id number. Should be of data type “TEXT”.
- Stop Name: Used for reference only, the stop name is pulled from the shapefile.
- For schedule times, use “HH:MM:SS” format (If greater than 24 hours, for ex. 1 AM following day, use “25:00:00”).
- Include both an arrival/departure time for all scheduled stops even if the stop is the first or last stop. Capture driver breaks using the difference between arrival/departure.
- Loop routes require that you enter the first and last stop twice in the schedule.
- Shape Id: Unique id for each unique variation of the route. Opposite directions usually have separate shape Ids. Note, these need to match the route shapefiles. Short trips are their own shapes.

## Stops Shapefile Rules

- Each stop must have a unique stop id which gets used in the schedule template.
- Include stop name for each stop (does not necessarily need to be unique, but is a best practice to do so).
- Each stop must have a stop_lat, and a stop_lon.

# Routes Shapefile Rules

- The Routes shapefile is optional. The Shape.txt file within GTFS informs the actual routing of the vehicle and can be helpful for using the systems data in the future, however, it is not critical for modeling travel times.
- Must have a record for each shape_id noted in the schedule.
- Each feature must have a shape_id. All other fields are only for reference.