Access in Appalachia
Concept and Methodologies–Final Report

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Report Prepared for:

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Executive Summary

Study Purpose

Historically, many Appalachian communities have been physically isolated, leading to and compounding a lack of access to jobs, health care, education, and more. The Appalachian Regional Commission was created, in part, to address the region's physical isolation and resulting socioeconomic setbacks. As the Interstate Highway System (IHS) was defined to avoid mountains when possible, substantial parts of Appalachia were left without modern IHS highway access–a problem observed and acknowledged by Congress when it approved the Appalachian Development Highway System (ADHS). Accessibility is intrinsically linked to economic development and opportunity. And while many segments of the ADHS have been completed, multimodal access and economic challenges remain in the Region. This study seeks to take a fresh look at transportation challenges through the lens of accessibility, to support ARC in its continued mission "Innovate, partner, and invest to build community capacity and strengthen economic growth in Appalachia."[1]

Shifts in funding make it more necessary than ever for ARC to work collaboratively with and support state and regional partners in identifying access constraints and opportunities for improvements. In an era of performance-based planning, States and regions are looking for the best available data on performance to guide their investment priorities. A better understanding of access conditions in the Region can also help ARC direct its own programs and grants. This project comes at a time when increasing availability of data and analytical tools offer newfound opportunities in quantifying accessibility.

The purpose of this study is to help define access in a way that is relevant to Appalachian needs and concerns, outline measurement approaches that capture key dimensions of access, and present a vision for applying those measures across the entire Appalachian Region.

Overview of Accessibility

Accessibility in this context refers to the ability of people and businesses to access desired activities, services, and goods with their available transportation options. Passenger transportation provides access to activities that people value, including work, shopping, recreation, health care, and education. Freight transportation ensures that households have goods available for purchase and provides businesses with the ability to ship and receive supplies and finished products. 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 three key dimensions: (1) the user group, defining the perspective of the measure (including the level of spatial aggregation), (2) the attractions,

[1] Weblink.

destinations, or opportunities to which access is being considered, and (3) network availability and performance, which dictates whether trips are possible by a given mode and how easy or hard the connection is (as measured by travel distance, time, cost, reliability, etc.).

Three Dimensions of Accessibility Definition

User Group	Attractions/Destinations	Network Availability and Performance
Access for whom/from where?	Access to where/what? How well does the destination meet the need?	Can you get there? How easy or hard is it?

Accessibility is an increasingly important lens through which to view transportation planning and investment because it focuses on the true end-goal of the transportation network: connecting people to opportunities and places they want to reach. Accessibility measurement can also be applied across modes, thus supporting a more comprehensive understanding of transportation options and performance.

How Access Influences Socioeconomic Outcomes

Accessibility is essential for economic development. Businesses of all types rely on the transportation system to access workers, inputs, markets, and collaborators. In Appalachia, accessibility is critical for the export of finished products or natural resources, to support tourism that rural regions rely on to grow their economy, and to connect businesses with skilled workers to compete in an increasingly global economy. Research shows that when businesses decide where to open new locations or relocate, accessibility factors rank among their top criteria. Accessibility improvements can generate economic development by attracting new businesses to a region or increasing the productivity of existing businesses.

Accessibility is also necessary for ameliorating economic distress. For example, the World Bank considers "access for all to economic and social opportunities" as central to their mission of reducing poverty and improving health and human development outcomes.[2] Access in many rural areas of Appalachia is characterized by remote locations, low population density, sparse transportation networks, lack of transportation services, and scarcity of desirable destinations. Specific accessibility challenges also arise for people who lack access to or the ability to use a personal automobile and therefore have difficulty reaching jobs, school, or other destinations. The effects of poverty and aging in Appalachia compound existing access issues. Improved access can consequently have a measurable impact on residents' well-being and businesses' economic viability.

Recognizing both the opportunities associated with good access, and the considerable challenges derived from constrained access, this study focuses on access measurement as an avenue towards better understanding conditions across Appalachia, pinpointing problem areas, and providing a platform for action.

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[2] World Bank, "Transport and Accessibility," October 28, 2016, Weblink.

Accessibility Measurement in Decision-Making

Access measures, like other performance measures, can be used to guide and shape each phase of the performance-based planning and programming process, as shown in the diagram below. At the highest level, within the visioning process, access can be acknowledged as an explicit goal or objective. This helps communicate the intention of subsequent planning and motivates the use of access measures to guide decision-making. Subsequently, within long-range planning, access measures can be used in assessment and diagnosis to determine how access varies across regions or modes and to identify constraints that may need to be addressed through transportation improvements. In developing programs of projects, access measures can serve as criteria for project evaluation and prioritization, helping decision-makers to direct resources towards their goal of improving access. Finally, access measures may be incorporated into performance monitoring to track changes over time including monitoring the effects of project improvements.

Access in Performance Based Planning and Programming

Visioning

- Integrating accessibility into agency or program goals and objectives

Planning

- Assessment: how does access vary across regions or modes?
- Diagnosis of the constraints that should be addressed

Programming

- Project evaluation and prioritization
- Directing resources towards improving access

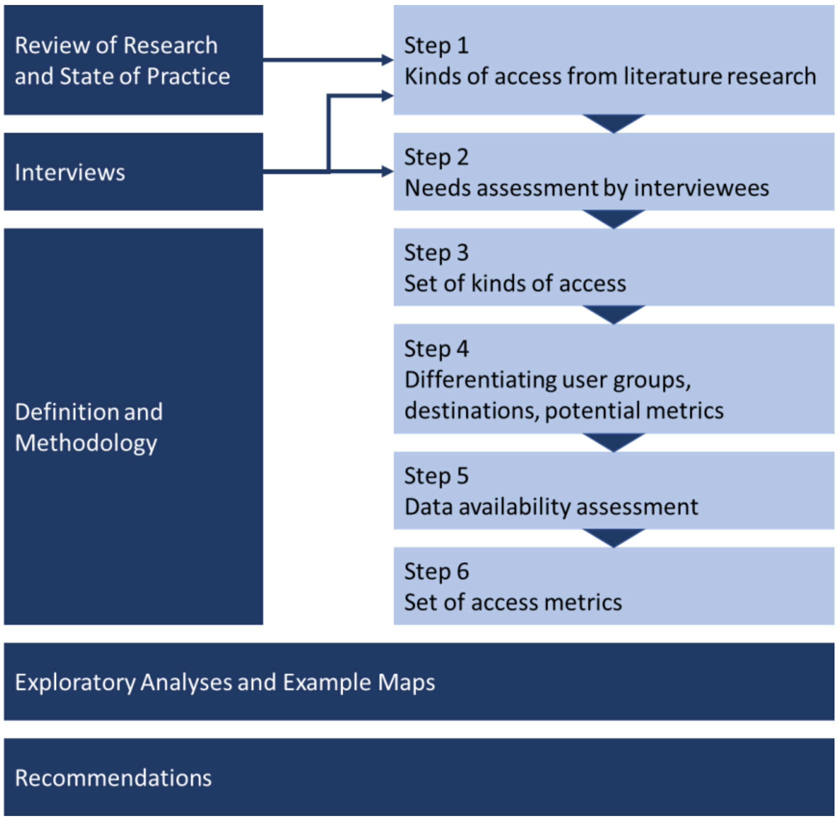
Performance Monitoring

- Monitoring the effects of improvements
- Tracking changes in accessibility over time

Study Approach

To arrive at a set of recommended accessibility metrics and methodologies, the research team followed a series of steps, which are documented in this report and shown in the figure below.

Study Approach



Findings from the *Review of Research and State of Practice* are summarized in Chapters 1 and 2. Chapter 1 presents the review and synthesis of accessibility research and data. It establishes a foundational understanding of the dimensions of access, the relationship of accessibility to economic development, and the unique nature of rural accessibility. Chapter 2 summarizes the state of practice for accessibility definition and measurement in Appalachian states. This includes a review of state practice in prioritization, long-range planning, and performance measurement, as well as examples from a range of other evaluation and planning contexts in Appalachia.

Development of a *Definition and Methodology* is addressed in Chapter 3. This incorporates an assessment of accessibility needs in Appalachia based both on the literature and a series of interviews with Appalachian stakeholders, a review of data availability, discussion of various approaches to measuring accessibility, and finally a recommended set of metrics and methodologies.

Exploratory Analyses and Example Maps are presented in Chapter 4. These analyses and maps represent proof-of-concept for selected measurement approaches and serve to test various implementation options to help guide the recommendations.

Recommendations for implementing access measures in Appalachia are summarized in Chapter 5.

A Vision for Measuring Access in Appalachia

From this study, the research team together with ARC developed a vision for measuring access in a way that is appropriate across Appalachia, addressing key dimensions of access identified to be critical to enhance the socioeconomic health of the Region. While implementation may be phased, the ultimate vision is for states, regions, and local government entities in Appalachia to incorporate key concepts regarding access into their decision making and resource allocation processes. An Analysis and Mapping Tool that is capable of producing maps and tables for geographies within the 13 Appalachian States for any of the recommended metrics may be one of the ways to facilitate adoption of more prominent access considerations in states' and local governments' processes. This approach would allow users to select a geography and metric (user group, mode, and destination) of interest and get the respective map and data tables. Such a system would enable users to explore:

- Access across different geographies within the 13 Appalachian States,
- Access for different user groups and sub-groups,
- Access by different modes, and
- Different types of access differentiated by destination type.

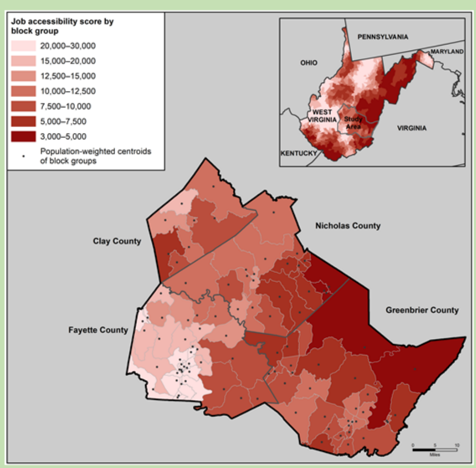
Vision for Access in Appalachia–Schematic Overview of Analysis and Mapping Tool (Example)

Selection Screen

Geography	User Group	Mode	Access Category
	People	Car	Health Care

Geography	Sub Group	Destination
State West Virginia	Population age 18-65	Level 1/2 Trauma Center

Analysis and Mapping Screen



County A	20,500
County B	16,300
County C	5,800
County D	2,300

Intended uses and audiences of the measurement approach presented here are summarized in the following table.

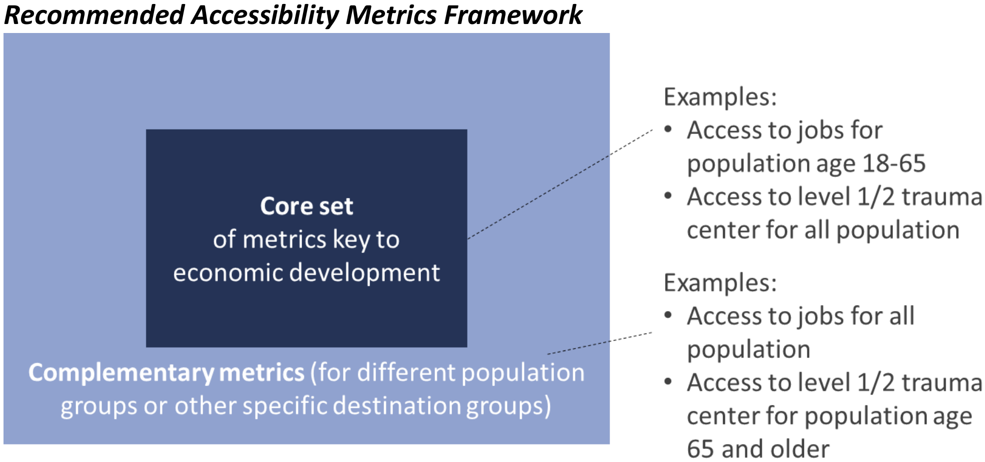
Intended Uses and Audiences of the Access in Appalachia Measurement Approach

Area	Description	Audience
Prioritization	• Present accessibility deficits in rural Appalachia • Allow for comparisons (within Region, within Appalachian states, to non-Appalachian rural areas)	State DOTs
Planning / Programming	• Better align economic priorities and transportation strategies and concepts	State DOTs, MPOs, etc.
Sensitization	• Raise awareness for accessibility deficits – beyond access to jobs – beyond car mode • Raise awareness for the relation between accessibility and economic outcomes	State DOTs, Other state agencies, Local/regional agencies, LDDs
Communication	• Demonstrate where transportation is constraining access	Service providers, Residents, Businesses

Recommended Accessibility Metrics

Recommended accessibility metrics are organized into a set of core metrics, and a supporting set of complementary metrics. This structure enables a focus on what matters most to economic development, while still recognizing the multidimensional nature of accessibility. It also recognizes that access needs to vary by user group, and that there may be multiple groups that merit consideration. Because significant portions of Appalachia are sparsely populated, it is important to weigh access measures by the population or employment affected—addressing the fact that low levels of access for unpopulated areas is not as problematic.

Recommended Accessibility Metrics Framework



The recommended metrics are organized by perspective and include:

- Metrics for businesses, capturing key items that businesses need access to 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 bridging gaps where physical access is poor.

The tables below summarize the core metrics. Additional detail on complementary metrics are provided in Chapter 3.5. For example, in the case of people-oriented metrics, a complementary analysis of access for populations affected by poverty is recommended.

Suggested Core Metrics for Businesses (Numbers refer to NAICS Industry codes)

Business Specification	Access to …		Destination specification
All	**B1. Labor**		Associate's 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

Suggested Core Metrics for Population

Population Specification	Access to …		Destination specification
Age 18–65	**P1. Job**		Employment
Age 18–24	**P2. Education**	**College**	All
All	**P3. Health care**	**A) Primary care**	General practice
All		**B) Trauma center**	All
All		**C) Addiction treatment center**	All substance abuse
All	**P4. Town centers**		All
All	**P5. Tourist destination**		National and State Designated

Suggested Core Metrics for Technology

Access to …	Sufficient Speed/Technology
T1. Mobile Broadband (i.e., Cell Phones)	LTE
T2. Fixed Broadband (i.e., at home)	≥ 25/3 Mbps download/upload

Recommended Methodologies to Build the Metrics

Based on the methodological considerations identified in this study, the results of test calculations, and from discussion with ARC, we suggest using the following outline of our methodologies for building the metrics:

- *Geographic unit:* Given the desire to conduct consistent comparative analysis, we recommend using a pre-defined standardized geography. For an adequate geographic granularity of measuring accessibility, we suggest using the smallest census unit with generally available associated data, the block group.

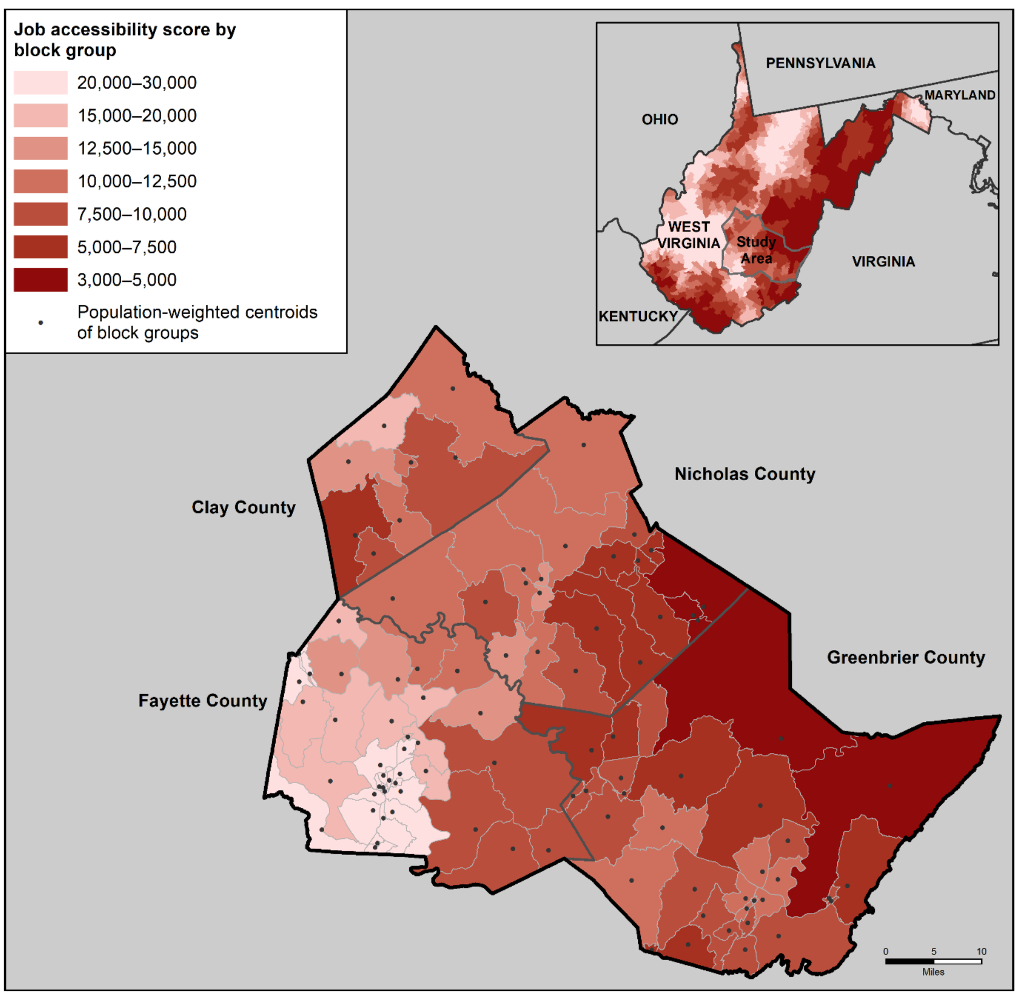
- *Representative origin- and destination points:* Calculations of travel times require that each block group have one or more points within it to serve as the start or ending point for measurement. We recommend the representative points be either the population- or employment-weighted centroids, depending on the measure's perspective, except where these are outside the block group, in which case the respective point would be replaced by the geometric centroid.
- *Functional form of measures:* Generally, the most appropriate functional form largely depends on the nature of the specific metric. 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. However, 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 destination:* 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).
- *Open source versus proprietary network data to determine travel times:* Open sources like OpenStreetMap do not currently appear to provide sufficient accuracy in network representation compared to proprietary alternatives like Esri's ArcGIS online. If resources are available, this suggests the use of proprietary network data for calculating drive times.
- *Average versus departure-time-specific network travel times:* While there do appear to be some effects from congestion during peak hours in the test conducted in this study, these effects are not significant enough to recommend that access measures be calculated at different times of day (e.g., access to jobs at peak and access for freight during off-peak). The consideration of time of day would also multiply the number of calculations required by a significant amount.
- *Truck specific network constraints and travel times:* The nature of truck versus car routing and the difference this can make for travel times merits further investigation and consideration, based on the findings from Chapter 4.
- *Public transit travel times:* Even though driving is the predominant mode for most people in the Region, we must also consider other modes to paint a more complete picture of access in Appalachia. The situation of people with no car available should also be part of the story told by this study. However, data about other modes, especially public transit, is currently not available in the necessary level of detail for large parts of rural Appalachia. ARC is in the process of commissioning a study about transit in Appalachia, which among other tasks will conduct an inventory of transit in the Region. This will be major source of information about transit characteristics and we suggest an implementation approach that will work with transit information of different kinds to generate zone-to-zone travel times.
- *Accessibility for households with limited car availability:* We suggest developing aggregate multi-modal accessibility metrics besides the mode-specific metrics for cars and transit. Their calculation would be based on weighted averages of mode-specific travel times, and the

weights would be determined by the geographic unit's share of carless and car-poor households.

Illustrative Example

The figure below provides an illustrative example of an accessibility metric implemented according to the recommendations developed in this study. This map illustrates variations in job accessibility across a test area in West Virginia. The employed metric counts jobs accessible from each zone, applying a decay factor that discounts jobs that are located further away. The smaller inset map shows how this is contextualized within the broader geography of West Virginia. If implemented across all 13 Appalachian States, this measure would provide an objective picture of relative advantage and disadvantage in terms of travel time access to jobs. The coloration on the map can be used to visually identify parts of the Region that have constrained access relative to their surroundings and that may merit special consideration when planning transportation improvements or evaluating projects. In addition, the underlying numeric accessibility scores can be incorporated in a quantitative fashion into project prioritization.

Illustration of Job Accessibility Using a Time Decay Function



Source: EBP analysis using data from LEHD, the Census extracted using IPUMS NHGIS, and ArcGIS online.

Implementation

This study lays out a framework and methodology for measuring key dimensions of access in the Appalachian Region. Some methodological questions remain open at the end of this research and would require further testing and decision-making within the context implementation to resolve. Nevertheless, the approach presented here is specified at a sufficient level of detail to allow interested states, regions, and localities—individually or in partnership with one another—to begin application of recommended metrics and methodologies. In particular, this report shows how different dimensions of accessibility can be represented with available data and offers insights into how to implement accessibility metrics in a manner that is sensitive to the unique needs of peoples and businesses in Appalachia.

To help advance the goal of more fully integrating access into transportation decision-making, this full research report is accompanied by a more concise companion document or "primer" offering guidance on incorporating access concepts into decision-making. The primer is designed to offer an entry point for analysts and decision-makers interested in learning about access issues and measurement, without providing the full methodological detail, theoretical background, and test applications that are included in this report.

In keeping with the vision presented here for measurement of access across Appalachia, ARC will in the future continue to work collaboratively with and support state and regional partners in identifying access constraints and opportunities for improvements, including possible additional research and development of technical assistance tools.

1 Accessibility Research

1.1 Overview

Chapter 1 of the report synthesizes existing research and data on access including related concepts of isolation, mobility, and connectivity to provide a basis for subsequent identification of the definition(s) of access and related methodological approaches to measure access. The research and practice review is targeted to serve the ultimate goal of this study: to develop a set of implementable metrics that can be used to identify shortcomings in access in Appalachia that are meaningful constraints on economic development, and that present opportunities for targeted improvement.

The following subsections focus on existing academic research. They mirror the key importance access has for socioeconomic outcomes in a region. Chapter 1.2 first describes the nature of accessibility. With the project's goals in mind, Chapter 1.3 analyzes especially the relationship between accessibility and economic development in rural areas. Grey call-out boxes are used to highlight key findings from the literature. Ways of measuring access are discussed in Chapter 1.4, and existing tools and data introduced, as far as they may be relevant to measure accessibility in Appalachia.

1.2 The Nature of Accessibility

Accessibility in this context refers to the ability of people to access activities, services, and goods given available transportation options.[3] Walter Hansen's frequently cited 1959 definition of accessibility is "the *potential* of opportunities for interaction [emphasis added]."[4] Accessibility levels depend on (1) how many destinations are within a certain area and (2) a person's level of mobility, or ability to travel between places.[5] In places with low-density settlement patterns like Appalachia, accessibility can be particularly dependent on levels of mobility, given the distances between relevant activities. The related concepts of isolation and connectivity also impact accessibility. Isolated places have lower transportation network connectivity between the places people travel to and from.

Passenger transportation provides access to activities that people value, including work, shopping, recreation, health care, and education. Freight transportation ensures that households have goods available for purchase and provides businesses with the ability to ship and receive supplies and finished products. When used as a performance measure, accessibility considers the degree to which transportation and land development patterns meet the access requirements of people and businesses, enabling their full participation in the economy and society.[6]

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3 Naomi Stein, "Accessibility," in Encyclopedia of the UN Sustainable Development Goals, eds. W. L. Filho, U. Azeiteiro, A. M. Azul, L. Brandli, G. Özuyar, and T. Wall (New York, NY: Springer, in press).

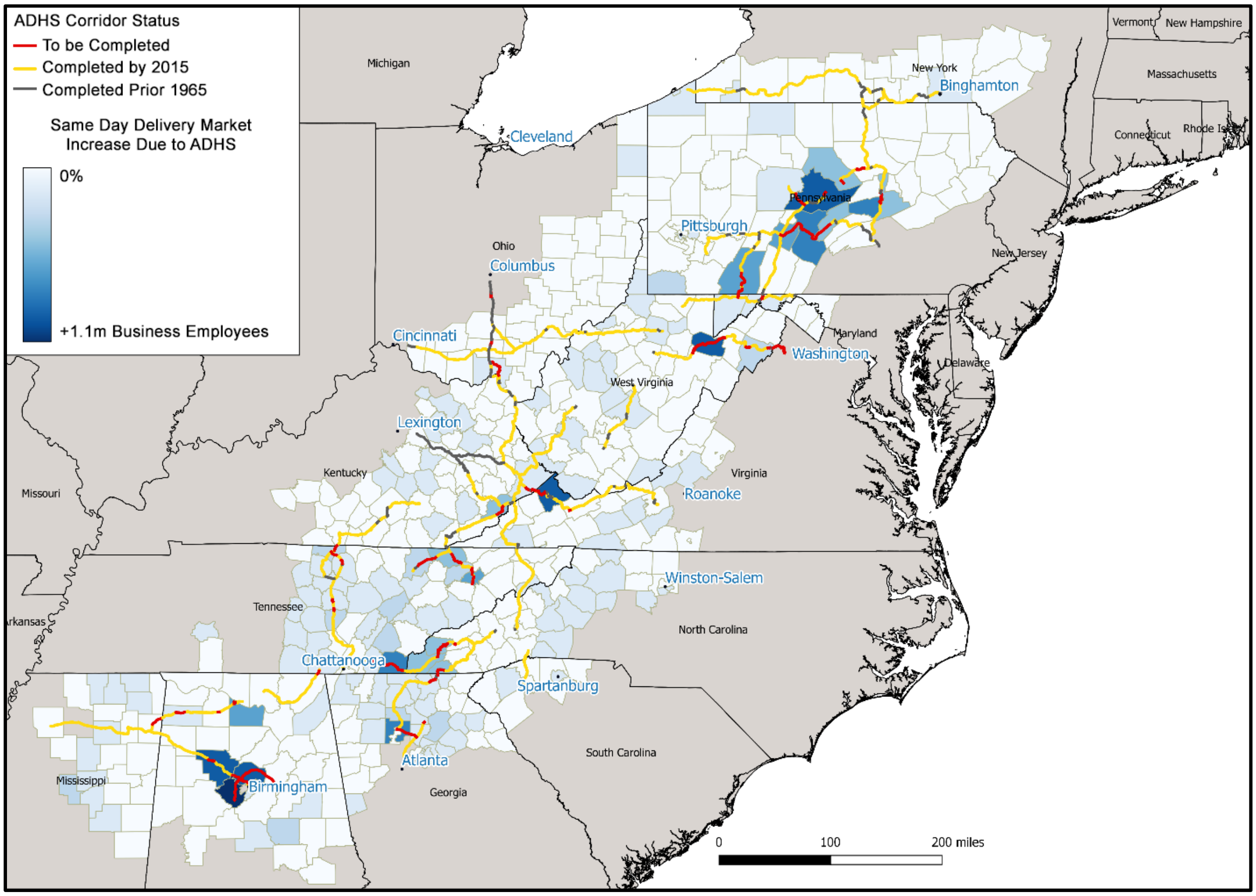
4 W. G. Hansen, "How Accessibility Shapes Land Use," Journal of the American Institute of Planners 25, no. 2 (1952): 73-76.

5 Susan Hanson, "Introducing Urban Transportation," in The Geography of Urban Transportation, eds. G. Giuliano and S. Hanson, 4th ed. (New York, NY: Guilford).

6 Stein, in press.

Figure 1 demonstrates with an example the use of access measures to understand how transportation network or performance changes can better connect people and businesses with their desired destinations. Completion of the Appalachian Development Highway System (ADHS) is projected to increase the same-day delivery market that is accessible for businesses in Appalachia within a four-hour one-way travel radius.[7] Expansion of access would enable Appalachian businesses to serve broader customer markets (both business-to-business markets and consumer markets) via same-day truck deliveries, thus improving their overall productivity and supporting economic growth.

Figure 1 Increase in Same-Day Delivery Market Access Attributable to ADHS Completion in 2045 (ARC 2017)



Source: ARC;
Same-day delivery market access is measured as a county of the number of business employees (a proxy for business activity and potential trading partners) accessible within a four-hour one-way travel radius

The broadest definition of accessibility acknowledges that access requirements can vary significantly across populations and different sectors of the economy. This means transportation should be used to address the access requirements of people with different abilities and socioeconomic status, and that transportation

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7 Appalachian Regional Commission, "Economic Analysis of Completing the Appalachian Development Highway System: Technical Report," EDR Group / WSP Parsons Brinckerhoff, July 2017, Weblink.

planners should recognize that safe, effective, and affordable access is necessary for inclusive and sustainable economic growth.[8]

1.3 Relationship to Economic Development

Accessibility is essential for economic development. Businesses of all types rely on the transportation system to access workers, inputs, markets, and collaborators. Regions reliant on manufacturing or resource-extraction tend to be proportionally more concerned with freight access to supplier and customer markets via transportation connections. Regions that are service-oriented, on the other hand, have proportionally greater requirements for access to skilled workers, broadband, and educational institutions. In Appalachia, accessibility is critical for the export of finished products or natural resources like coal, or to support the tourism that rural regions rely on to grow their economy. Ways of measuring accessibility for rural exporters include average travel times to airports, marine ports, and rail facilities.[9] For companies that export internationally, access is not only about connectivity but also trade tariffs, non-tariff measures, and procedural obstacles.[10]

Accessibility improvements can generate economic development by attracting new businesses to a region or increasing the productivity of existing businesses. When businesses decide where to open new locations or relocate, many list accessibility factors among their top criteria.[11] Through increased market access and intermodal connectivity, firms can increase their sales and use capital and labor more efficiently. The term "agglomeration economies" refers to the business productivity benefits associated with industry clustering and improved access to workers, suppliers, and customers. These economic forces tend to encourage spatial clustering at various geographic scales and lead to firms being more productive when they have access to larger labor, customer, or supplier markets, or have a greater ability to interact with other firms.[12] These productivity impacts from accessibility vary significantly by industry sector.[13]

Remote areas like those throughout Appalachia tend to be poorly served by freight and transit operators due to low demand. Because of the effects of poverty and aging in Appalachia, specific accessibility challenges arise for people who lack access to a personal automobile and therefore have difficulty reaching jobs, school, or other destinations. Some areas also have limited roadway network coverage because of high construction costs associated with topographical barriers like mountains or rivers, coupled with less

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[8] Ibid.

[9] Economic Development Research Group, Inc., Handbook: Assessing Local Economic Development Opportunities with ARC-LEAP (Washington, D.C.: Appalachian Regional Commission, January 2004), Weblink.

[10] United Nations Conference on Trade and Development, Market Access, Trade and Sustainable Development (New York, NY: United Nations), Weblink.

[11] Economic Development Research Group, Inc., and Investment Consulting Associates, The Role of Transportation in Private Firm Site Selection Decisions: A Primer for Transportation Planners and Decision-makers (Washington, D.C.: United States Department of Transportation, September 2018), Weblink.

[12] Glen Weisbrod et al., Assessing Productivity Impacts of Transportation Investments, NCHRP Report 786 (Washington, D.C.: Transportation Research Board, 2014), Weblink.

[13] Brian Alstadt, Glen Weisbrod, and Derek Cutler, "The Relationship of Transportation Access and Connectivity to Local Economic Outcomes: A Statistical Analysis," Transportation Research Record 2297, accessed December 11, 2018, Weblink.

dense settlement patterns and other spatial constraints.[14] Some industries must be near natural resources, making access to remote areas critically important.

Economic development depends on accessibility because businesses require cost-effective access to inputs, customers, workers, and collaborators. Access improvements generate economic growth by attracting new business or improving the productivity of existing business.

What is Different about Rural Accessibility?

Access in many rural areas of Appalachia is characterized by remote locations, low population density, sparse transportation networks, lack of transportation services, and scarcity of desirable destinations. Lack of access is a major impediment to residents' well-being and businesses' economic viability. This may shift the focus from being able to access as many similar destinations as possible to being able to access one within a reasonable amount of time.

A FHWA report dedicated to rural accessibility examined access issues for rural counties, including metropolitan counties below 50 persons per square mile and non-metropolitan area counties. The study deduces measures for rural accessibility by first profiling three different types of rural communities and their primary rural economic and social issues. From there, it zeroes in on different dimensions of accessibility that relate to these economic and social challenges (Table 1).[15] This approach illuminates both how accessibility can be considered specifically in relation to the dominant challenges of an areas, and how those challenges can vary even amongst rural communities.

Table 1 FHWA Analysis of Rural Community Types and Challenges

Rural Economic Concentration	Primary Economic or Social Issue	Transportation Access Issues
Destination Communities: have natural environments and amenities that tend to attract tourists, second-home owners, and retirees	Adequate Labor supply	*Residents*–job access via transit, resident elderly access to public transportation *Businesses*–tourist access to intercity transportation (interstate/air/rail). Access to tourism markets
Exurban Communities: Growing counties generally located in proximity to urban areas	Local cultural, recreational, shopping opportunities	*Residents*–lack of access to modal options, have long distances to travel to social, shopping, recreational, cultural opportunities
Production Communities: depend on economic drivers that are declining such as mining, agriculture, and manufacturing.	Declining job base in some communities, loss of population, social isolation, uncontrolled growth in some communities	*Business*–access to rail lines, access to ports, airports, intermodal facilities; farm to market access; access to consumer markets *Residents*–long distances to access economic, educational, health care, social resources. Internet access may reduce transportation burden

Source: Adapted from FHWA, Developing Performance Measures for Rural Access Transportation.

14 Stein, in press.

15 Federal Highway Administration, Developing Performance Measures for Rural Access Transportation, 11/15/2013

While rural areas have diverse economies and needs, they often share common challenges in that their economic development can be especially hindered by insufficient accessibility.

How Access Relates to Economic Distress and Prosperity

Accessibility is necessary for ameliorating economic distress. The World Bank considers "access for all to economic and social opportunities" as central to their mission of reducing poverty and improving health and human development outcomes.[16] Changes in accessibility can also portend economic decline. For example, if travel speeds between two places decline, there is an incentive for businesses to relocate to a region with better accessibility.[17] This relocation represents a loss of economic activity unless new businesses fill their place.

Workers in rural areas face special challenges related to accessing job opportunities given the (often) greater distances between homes and workplaces. This is especially true for workers without a car. This is problematic because public transportation is unavailable in many rural areas. Only 0.5% of rural residents use public transportation, compared with 6% of urban residents.[18] When it is available, systems are often limited to single county or municipality, limiting the number of destinations reachable without a car.[19] Demand-response transit provided by human service agencies is the only option in many places, filling an important gap for people who lack other mobility options. Rural transit services may also have higher costs per rider than urban services given greater travel distances and lower population densities.[20]

Investments in the Appalachian Development Highway System (ADHS) between 1965—2015 stimulated economic impacts that would not have occurred otherwise and continue to transpire today. While travel time and reliability gains for business and commercial travel and freight will continue to account for part of the impacts of the ADHS completion, access benefits will have measurable effects on business productivity and related economic impacts in Appalachia.[21] Rural areas also have less walking and biking infrastructure than cities, and many trips are too long to be made using these modes, meaning driving is the only option for most people.

The economic value of providing connectivity is usually assessed based on how many vehicles or people use a connection. However, beyond economic feasibility standards, rural roads can be seen as lifelines for people who live in isolated areas. Those rural roads may be used by a relatively small group of individuals who heavily depend on them and to whom the road provides significant

16 World Bank, "Transport and Accessibility," October 28, 2016, Weblink.

17 Genevieve Giuliano and Ajay Agarwal, "Land Use Impacts of Transportation Investments," in The Geography of Urban Transportation, eds. G. Giuliano and S. Hanson, 4th ed. (New York, NY: Guilford).

18 Jeremy Mattson, "Rural Transit Factbook 2015," Upper Great Plains Transportation Institute, June 2015, Weblink.

19 Eileen S. Stommes and Dennis M. Brown, "Moving Rural Residents to Work: Lessons from Eight Job Access and Reverse Commute Projects," Transportation Research Record: Journal of the Transportation Research Board of the National Academies 1903 (2005): 45–53.

20 Dennis Brown and Eileen Stommes, "Rural Governments Face Public Transportation Challenges and Opportunities," last modified February 1, 2004, Weblink.

21 Appalachian Regional Commission, "Economic Analysis of Completing the Appalachian Development Highway System: Technical Report," Economic Development Research Group, Inc. (EDR Group) and WSP/Parsons Brinkerhoff, Washington, D.C.:, July 2017, Weblink.

benefits.[22] The World Bank argues that the primary objective of rural roads with low volumes is to provide "basic access"—defined as the "minimum level of infrastructure required to sustain socio-economic activity."[23] The condition of the road may be regarded secondary as compared to its mere availability.

In places with high unemployment, improving access can increase the number of job opportunities available to residents.[24] This is especially true in metropolitan areas, where residential segregation and the dispersal of jobs reduce employment opportunities for low-income residents that are reachable within reasonable travel times or via public transit.[25] So-called "job sprawl" and the suburbanization of poverty have compounded these effects for low-income workers, as distances between households and employment centers have grown and jobs have become less accessible via public transit.[26] Research finds that workers who lack vehicle access are less likely to be employed,[27] while conversely vehicle access increases the probability of being employed and being able to leave government welfare support.[28] Residents' inability to reach job interviews, training opportunities, or workplaces contributes to persistent unemployment and poverty. Economic development professionals and community members also routinely report on access barriers as a limitation to economic participation.[29]

Insufficient access to jobs and other socio-economic activities can prevent people from benefiting from overall economic development, thus contributing to economic distress. This is particularly true for those without access to cars or insufficient modal options.

What does this mean for the kinds of access we are focusing on?

At this point in the development of accessibility perspectives for the Appalachian Region, the review of existing research and current practices reveals various kinds of access that appear important to different groups of people or businesses. Subsequent Chapters of this study will develop a structure to define kinds of access we are focusing on and to elaborate methodologies to measure those. This review of research and practice merely collects kinds of access which have been the object of research.

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22 S. Johansson, "Socio-Economic Impacts of Road Conditions on Low Volume Roads, Executive Summary," ROADEX III Northern Periphery (2006).

23 World Bank, "Notes on the Economic Evaluation of Transport Projects: Low Volume Rural Roads," Transport Note No. TRN-21 (Washington, D.C.: World Bank, 2005).

24 EDR Group and WSP/Parsons Brinkerhoff, 2017.

25 Huiping Li, Harrison Campbell, and Steven Fernandez, "Residential Segregation, Spatial Mismatch and Economic Growth across US Metropolitan Areas," Urban Studies 50, no. 13 (2013), Weblink, and University of Chicago, "Longer commutes disadvantage African-American workers," ScienceDaily, February 15, 2014, Weblink.

26 Steven Raphael and Michael Stoll, "Job Sprawl and the Suburbanization of Poverty," Brookings, March 30, 2010, Weblink.

27 Greater New Haven Job Access and Transportation Working Group, "How Transportation Problems Keep People Out of the Workforce in Greater New Haven," DataHaven, December 2014, Weblink.

28 Tami Gurley and Donald Bruce, "The effects of car access on employment outcomes for welfare recipients," Journal of Urban Economics 58(2):250–272, September 2005.

29 Laura Ducceschi and Erin Mierzwa, "The Role of Transportation in Fostering Economic Mobility in Northeastern Pennsylvania," CASCADE NO. 97 FALL 2017. Weblink.

Access to Customer, Supplier, and Labor Markets

From the perspective of business, access to markets is fundamental to economic growth and development, particularly in Appalachia. In developing a model to forecast the effect of transport proposals on business location decisions, the behavior of businesses is best understood as a response to a business's own operational factors that are in turn affected by transportation—namely access to workforce, customers, and suppliers.[30] These dimensions are conceptually distinct and can act at different geographic scales. For example, whereas workforce access applies within a commuting shed, customer access can range from very local (e.g., for a convenience store) to highly global (e.g., for a specialized manufacturer). Supply chains can similarly vary widely in scale. Connectivity to long-distance transportation network (airports, marine ports, intermodal rail) broadens the geography of market access, particularly in a globalized economy and may be considered as its own dimension of access as well. For example, in Amazon's highly publicized request for proposals for a second headquarters, the company defined a set of minimal transportation access requirements including "Proximity to major highways and arterial roads" within 1—2 miles and "Proximity to International Airport" within approximately 45 minutes.[31]

One of the challenges of understanding market access is that access requirements vary meaningfully across industries and across different business functions. The most straightforward variation is relative reliance on passenger versus freight transportation. Most industries have some delivery and shipping requirements, but manufacturing and logistics sector businesses are particularly sensitive to their ability to efficiently receive and ship goods. Conversely, all industries rely on labor, but labor market access may be proportionally more important to professional, scientific, technical, or management industries whose products are primarily knowledge-based and therefore need access to a deeper pool of labor.

Research on the influence of transportation access on patterns of industry-specific employment concentration and productivity shows how different types of transportation access are more relevant to different industry sectors:[32]

- The scale of population accessible within a 40-minute radius (a labor market or consumer spending market measure) is a significant factor for both trade and service industries, but is generally less strong for manufacturing, given that manufacturing also depends to a large extent on supply chain considerations that act at a larger geographic scale.
- The amount of business activity within a 3-hour or 4-hour travel time threshold is particularly important for manufacturing and agriculture but is less significant for service industries. Employment is used as a proxy measure to represent businesses within a same-day delivery market scale.
- Commercial airport access is most important for professional, scientific, and administrative businesses that rely on employee travel, to recreation industries that are tourism-reliant, and to specialized manufacturers that rely on air cargo services.

30 J. Swanson, "The Impact of Transport on Business Location Decisions. Association for European Transport," Washington, D.C.: Transportation Research Board, 2006, Weblink.

31 Amazon, "Amazon HQ2 RFP," 2017, Weblink.

32 Alstadt, Weisbrod, and Cutler, 2012.

This points to a necessary balance between, on the one hand, wanting detailed differentiation of individual access requirements through the use of multiple measures and, on the other hand, wanting a relatively manageable (small) number of measures that proxy well for a range of access needs but necessarily are more general.

Similar market access dimensions to the above can also be considered from the individual perspective in terms of access to jobs or access to consumer goods and services. However, they are not the only kind of access potentially preventing rural residents from leading prosperous lives. For example, when the federal Job Access and Reverse Commute program was established in 1998, access to workforce training and childcare were also key considerations.[33] Lack of childcare can prevent people from getting to a job interview or attending class to advance their education. When residents' lack of access to childcare or education subsequently prevents them from getting and keeping jobs, the human capital within their community remains underdeveloped. The following chapters explore additional kinds of access and how each matter for different groups of people living in rural areas.

Economic development in different business industries may depend on different kinds of access or requires different qualities of access.

Access to Food

Ensuring that people have access to healthy and affordable foods is a public health objective. According to the United States Department of Agriculture, "Consumer choices about food spending and diet are likely to be influenced by the accessibility and affordability of food retailers."[34] Newer research, however, finds more limited impacts of food deserts or food swamps on people's diet quality. One study states that food deserts have a much smaller effect on obesity than food swamps.[35] [36] Another study analyzing nutritional inequality found that providing low-income households the same grocery shopping choices as high-income households reduces nutritional inequality by only 9%, while the remaining 91% are related to this group's demands.[37]

However, the presence of supermarkets and grocery stores may be an important factor for a community to attract residents and businesses.

While access to food has a complex relationship to health outcomes, access to food is both a public health objective and can help make a community more attractive for residents and businesses.

33 Stommes and Brown, 2005.

34 United States Department of Agriculture, "Food Access," last modified February 13, 2018, Weblink.

35 Kristen Cooksey-Stowers, et al., "Food Swamps Predict Obesity Rates Better Than Food Deserts in the United States," Int J Environ Res Public Health, 2017 Nov, 14(11): 1366, Weblink.

36 Ibid., "Food swamps have been described as areas with a high-density of establishments selling high-calorie fast food and junk food, relative to healthier food options."

37 Hunt Allcott, Rebecca Diamond, Jean-Pierre Dubé, Jessie Handbury, Ilya Rahkovsky, and Molly Schnell, "Food Deserts and the Causes of Nutritional Inequality," NBER Working Paper No. 24094, Issued in December 2017, Revised in November 2018.

Access to Education

While 42% of the nation's young people between age 18 and 24 are enrolled in any higher education institution, only 29% of rural people are.[38] While there are other individual and social barriers to higher education like limited aspirations and several individual and family factors, research shows that distance to college also correlates with students' choices to apply or enroll. This is the case even more so in rural areas since lower socioeconomic status is more common in rural areas and substantial savings can be achieved when college students are able to carry on living at home.[39]

For many rural people, community colleges provide the only accessible opportunity for higher education. About two-thirds of public two-year colleges serve rural communities, providing a critical path to careers and four-year universities.[40] Research has shown that rural counties with an established community college or university have experienced greater job growth over time than counties without institutions of higher education.[41] Also for rural community college students travel to school has been shown to impact their decision to re-enroll each semester.[42] Access to educational opportunities extends to elementary schools. Research on elementary schools in rural West Virginia found that schools with greater accessibility are associated with improvements in student achievement.[43] This highlights the importance of rural accessibility for regions trying to grow the human capital of their residents, a necessary ingredient for prosperity given today's skill-driven economy.

Economic development may be hindered where potential students do not have good access to colleges and other schools and where employers do not have access to an adequately educated workforce.

Access to Health Care

Out of the 420 counties in the Appalachian Region, 149 rank in the worst national quintile regarding Years of Potential Life Lost (YPLL). Most of those counties are located in the central and southern parts of the Region. Relative to the nation, the health care situation in those parts even has worsened over the last three decades[44]. Transportation is generally seen as one of three main barriers to health care

38 National Center for Education Statistics: Rural Education in America, Data for 2015, Weblink.

39 Molefe, A., Burke, M. R., Collins, N., Sparks, D., & Hoyer, K. (2017), "Postsecondary education expectations and attainment of rural and nonrural students" (REL 2017–257), Washington, DC: United States Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Midwest, Weblink.

40 Science Foundation Arizona, "Making a Difference: Community Colleges Are Key Drivers of Rural Development," accessed December 11, 2018, Weblink.

41 Andrew Crookston and Gregory Hooks, "Community Colleges, Budget Cuts, and Jobs: The Impact of Community Colleges on Employment Growth in Rural United States Counties, 1976–2004," Sociology of Education 84, no. 4 (2012): 350–372.

42 Shanda Carter, "Access Barriers To Higher Education For Rural Community College Students," PhD dissertation, University of Arkansas, 2014, Weblink.

43 Emily Talen, "School, Community, and Spatial Equity: An Empirical Investigation of Access to Elementary Schools in West Virginia," Annals of the Association of American Geographers 91, no. 3 (2001): 465–486, accessed December 11, 2018, Weblink.

44 Appalachian Regional Commission, "Health Disparities in Appalachia," August 2017.

for rural population, with cost and language being the other two[45]. For the Appalachian Region, a lack of transportation was for instance revealed as a barrier for residents to attend smoking cessation programs[46]. Multiple studies found a positive relationship between vehicle access and health care. One of them found in 12 western North Carolina counties that the possession of a driver's license led to about twice as many doctor's visits. Those who had a family member or a friend, who could provide transportation, had 1.58 more visits than those who did not.[47]

The ability to access medical appointments is critical to the overall health and welfare of society. This is especially true for vulnerable rural populations, including older adults, people with disabilities, low-income individuals and families, and veterans or those who otherwise have unique healthcare needs.[48] Older adults tend to have lower mobility levels, which negatively affects their ability to access health facilities and services.[49] This restricts their choice of health care providers and increases their risk of social isolation.

The Rural Health Information Hub, a national clearinghouse on rural health issues, identifies the following negative public health-related impacts caused by a lack of accessibility: [50]

- Increase in delayed or missed trips to receive healthcare services
- Disruption in ongoing treatments and services for chronically ill patients
- Travel distance to health services and the related costs affect patients' health care decisions
- Travel time spent to access health care can affect patients physically and cause stress
- Use of some medications, like insulin, declines as patients live farther from their source of care

Approximately 3.6 million Americans miss or delay non-emergency medical care each year because of transportation-related issues.[51] Vehicle availability is consistently associated with increased access to health care.[52] The people who are unable to access non-emergency medical care tend to be disproportionately low-income, female, minority, less educated, and older. The result is higher total medical costs because people forgo disease management and preventive care. In some cases, the

45 National Association of Community Health Centers: Removing Barriers to Care: Community Health Centers in Rural Areas, Weblink.

46 Appalachian Regional Commission, "Health Disparities in Appalachia," August 2017.

47 Arcury, TA, et al.: Access to Transportation and Heath Care Utilization in Rural Region. Journal of Rural Health. 2005 Winter.

48 Rural Health Information Hub, "Transportation to Support Rural Healthcare," January 11, 2016, Weblink.

49 Antonio Paez, et al., "Accessibility to health care facilities in Montreal Island: an application of relative accessibility indicators from the perspective of senior and non-senior residents," International Journal of Health Geographies 9 (2010), accessed December 11, 2018, Weblink.

50 Rural Health Information Hub, "Transportation to Support Rural Healthcare," January 11, 2016, Weblink.

51 National Academies of Sciences, Engineering, and Medicine, "Cost-Benefit Analysis of Providing Non-Emergency Medical Transportation," Washington, D.C.: The National Academies Press, 2005, Weblink.

52 Samina T. Syed, Ben S. Gerber, and Lisa K. Sharp, "Traveling Towards Disease: Transportation Barriers to Health Care Access," Journal of Community Health 38 (2013): 976–993.

savings from non-emergency medical care exceed the cost of providing necessary transportation services to these vulnerable populations.[53]

Opioid addiction is considered a public health epidemic in the United States and especially in some Appalachian states. Transportation factors into this issue in at least two ways. First, opioid deaths and injuries have increased the most in rural areas where emergency medical response times are longer. Second, opioid addicts living in rural areas face greater barriers to treatment given a lack of public transportation and longer travel distances relative to urban areas.[54] Opioid treatment programs (OTPs) are a common form of care, but they require daily visits by patients—a significant challenge for those who cannot afford to travel that often or do not have access to a vehicle or other option. According to research by the National Rural Health Association, “many rural residents enrolled in OTPs report that the transportation requirements are so extensive that they ostensibly prevent [OTPs] from working.”[55] An OTP is the only place where methadone, a drug used to treat opioid dependence, can be legally prescribed.

The Children’s Health Fund in New York City developed the Health Transportation Shortage Index (HTSI) to identify areas where a lack of transportation makes it difficult to receive health care.[56] The index expands on the concept of Health Professional Shortage Areas (HPSAs)—or areas with a low ratio of health care providers to population—by considering the role of transportation. The authors consider both public transit availability and vehicle availability, using an area’s poverty level as a proxy for the latter.

Access to health care improves health outcomes and is therefore widely considered an underlying factor of economic development.

Access to Broadband

While only 7% of the United States population does not have broadband access in their neighborhoods (25 Mbps download or faster), in rural America this share is 27.4%. A study by The Brookings Institute further looks at demographic characteristics and concludes that differences in broadband service stem from geography rather than from demographic characteristics.[57]

In an increasingly networked economy, broadband connectivity is critically important to the business community, contributing to increased productivity, competitiveness, and efficiency.[58] Specific business functions that rely on high-speed Internet include marketing, data management, supply chain management, and cloud computing. This means that some industries benefit more from

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53 National Academies, 2005.

54 Christine Hancock, et. al, “Treating the Rural Opioid Epidemic,” National Rural Health Association, February 2017, Weblink.

55 Ibid., p. 4.

56 Roy Grant, et al., “The Health Transportation Shortage Index: A New Tool to Identify Underserved Communities,” Children’s Health Fund, 2012, Weblink.

57 Tomer, A., et al.,” Signs of Digital Distress,” The Brookings Institute, Metropolitan Policy Program, September 2017.

58 Sara Lawrence, Zachary Oliver, Michael Hogan, and Sara VanLear, “Program Evaluation of the Appalachian Regional Commission’s Telecommunications and Technology Projects: FY 2004–FY 2010,” Washington, D.C.: Appalachian Regional Commission, November 2015, Weblink.

broadband access than others. At a regional level, telecommunications infrastructure can help attract businesses and foster entrepreneurship, in turn creating jobs and generating tax revenue.

Beyond its importance to business, access to broadband internet is now recognized as a prerequisite for individual access to services such as health care, education, and employment.[59] The internet has become an “indispensable resource for workers,” with many people using it to apply for jobs and telecommute.[60] These benefits are especially valuable in rural areas, where employment centers are more dispersed. Internet access affects rural residents’ ability to attend post-secondary education and access medical care through telemedicine.[61] However, in rural areas, more than one in four households lack access to 25 Mbps broadband.[62]

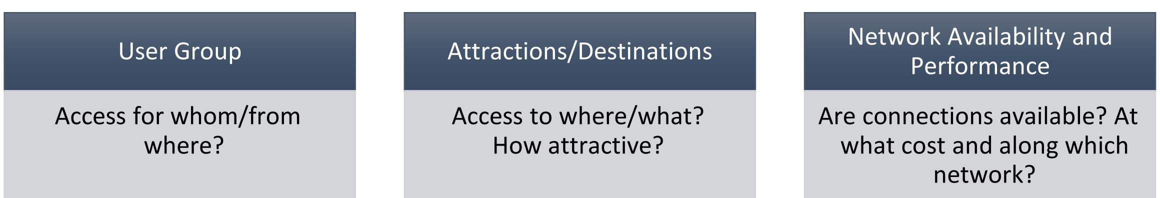
> Where educational institutions, health care providers and employers are not sufficiently accessible to people, broadband access may serve as a substitute for physical access, providing people with some of the benefits of economic development.

1.4 How Accessibility Is Measured[63]

Dimensions and Options for Typical Area-Based Access Measures

Comprehensive accessibility definitions typically address three dimensions as shown in Figure 2 below: (1) the user group, defining the perspective of the measure (including the level of spatial aggregation), (2) the attractions, destinations, or opportunities to which access is being considered, and (3) network availability and performance, which dictates whether trips are possible by a given mode and the “impedances” (i.e., travel distance, time, cost, reliability, etc.) that limit access between users and attractions/destinations.

Figure 2. Three Dimensions of Accessibility Definition



[59] Federal Communications Commission, “Remarks of Commissioner Mignon L. Clyburn at the Launch of the Mapping Broadband Health in America Platform,” Microsoft Innovation and Policy Center, August 2, 2016.

[60] Ibid.

[61] Carter, 2014.

[62] Adie Tomer, Elizabeth Kneebone, and R. Shivaram, “Signs of Digital Distress: Mapping broadband availability and subscription in American neighborhoods,” Washington, D.C.: Brookings, September 2017, Weblink.

[63] The discussion in this section draws on prior research by the authors including the framework established in: Stein, N. (In Press), “Accessibility,” In: Filho, W.L., Azeiteiro, U., Azul, A.M., Brandli, L., Özuyar, G., Wall, T. (Eds) Encyclopedia of the UN Sustainable Development Goals, Springer.

The dimensions in turn define a series of measurement decisions that once answered result in a specification of the form of an access measure. These are discussed below, along with Appalachia-specific measurement considerations based on the above research review.

User Group. The user group defines the perspective of the measure, including the level of spatial aggregation. In practice, this means choosing the point in geographic space from which access to opportunities is measured. Analysts have a number of options.

The first two options are most relevant if access measures are to be applied in an automated or uniform fashion across an entire region:

1. Choose centroids within a defined zonal system. Zones may be Traffic Analysis Zones within a travel model or other standard defined geographies such as those defined by the census (as in Virginia's SMART SCALE prioritization, for example[64]). Centroids can be chosen as geographic centers of a zone or as activity-weighted centroids to most closely approximate locations that generate trips.
2. Using a standardized grid system. Whereas the above approach can have zones of different sizes, this type of analysis calculates access for every cell within a uniform grid (e.g., 1 km x 1 km as in Jaber, Wagner, and Papaioannou n.d.[65])

Both of the above options can be chosen to deliver different levels of geographic detail or spatial resolution.

The third option is used to focus analysis to key areas of interest and requires a prior step of analysis:

3. Focus on key locations of interest. This approach focuses the analysis rather than attempting to develop measures of access for every location within a region. For example, Minnesota has reported measurement of the *percent of major generators with appropriate roadway access to interregional corridors (IRCs) and major highways*.[66] Selection of key locations can be guided by professional judgment or a separate spatial analysis of the distribution of key points of interest, population, or employment.

The fourth option is a conceptual hybrid of the above three:

4. Calculate an average level of accessibility, weighted by measure of the affected user group: This approach would calculate a level of access for every zone or grid cell in a region and then calculate a weighted average access measure across the whole region using a weight that reflects the numbers of users affected. This could be an aggregate measure such as total population or a policy-targeted measure such as number of people living below the poverty line.

Appalachia-Specific Considerations: Based on the review of research and practice, and a current understanding of Appalachian development objectives, the following are Appalachia-specific

64 Commonwealth Transportation Board, "SMART SCALE Technical Guide," Weblink.

65 A. A. Jaber, N. Wagner, and D. Papaioannou, "Benchmarking Accessibility to Services Across Cities," Weblink.

66 Minnesota DOT, Minnesota Statewide Freight Plan, 2005, Weblink.

considerations for selection of the user group that will be further investigated/refined through subsequent research:

- Given the desire to conduct consistent comparative analysis, states, regions, and local governments should consider using a pre-defined standardized geography for at least some of its selected access measures (rather than relying on a non-standardized process for selecting locations of interest).
- Because significant portions of Appalachia are sparsely populated, it may be important to weigh access measures by the population or employment affected (addressing the fact that low levels of access for unpopulated areas is not as problematic).
- In addition, given the focus on economic development and support for disadvantaged populations, states, regions, and local governments may wish to include analysis weighted by indicators of disadvantage.

Attractions/Destinations. Selections of attractions/destinations defines the "access to what" component of the analysis. There are a wide range of options available here, but they can be broken down broadly into two approaches:

1. Activity access: In this approach, analysts measure access to specific activities that are typically selected to reflect either individual or firm-level requirements. As discussed above, this might include access to jobs, education, health care, or other services for people or access to employees, markets, or customers for companies. Some analyses simply count the number of establishments of a certain type (e.g., schools, restaurants), while others use indicators of magnitude such as employment or population to account for the scale of the opportunity.[67] Analysts may also define a hierarchy of importance, granting a greater number of points to activities of a certain kind, quality, or scale. This is the case in North Carolina's prioritization which differentiates between access to major versus secondary centers.[68]

   Common aggregate measures of attraction/destination opportunities include counts of total employment or population, with employment serving as a proxy for business activity, and population proxying for labor force or customer markets. Population can also proxy for opportunities for social interaction or, barring specific information about establishment locations, for services that tend to be spatially co-located with population centers. More detailed analysis is possible by, for example, focusing on specific populations such as skilled workers, target industries as measured by sector-specific employment, or detailed destinations types such as differentiating level 1 or 2 trauma centers from other medical service providers. In practice, detailed measurement options may be limited by data availability, depending on the category of interest and the desired geographic detail.

   Measures can combine a component to express the access to a destination and another component for the number of people that benefit from this access. An FHWA study suggests

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67 For example, population to proxy for labor market availability and employment to proxy for buyer-supplier relationships between firms as in Alstadt, B., Weisbrod, G., & Cutler, D. (2012, March 5). The Relationship of Transportation Access and Connectivity to Local Economic Outcomes: A Statistical Analysis. Transportation Research Record, 2297.

68 North Carolina Department of Transportation, Prioritization 5.0 Master Presentation, July 2018, Weblink.

measures of this kind, considering both the percentage of a county's population within X miles of a destination and the distance to the nearest destination of a specific kind (major job center, education, health care and population center).[69]

2. Network access: Network access measures focus on access to important nodes on the transportation network such as highway interchanges, transit stations, freight rail terminals, ports, and airports. These types of measures can be used to bring policy attention to the availability of modal options or to proxy for the greater levels of access provided by these network "entry points," given that most networks used for accessibility analysis are not full intermodal. Indicators can simply be counts of the accessible nodes or use indicator of the scale of connection provided such as tons of freight handled at a freight rail terminal or number of destinations served by air service at an airport.[70]

Appalachia-Specific Considerations: The following are Appalachia-specific considerations for selection of attractions/destinations that should be further investigated/refined through subsequent research:

- State, regional, and local government entities within Appalachia should consider prioritizing destinations based on a hierarchy of need. This hierarchy can be investigated through engagement with key stakeholders.
- Given the sparseness of the transportation network in some parts of Appalachia, measures that focus on network access may also be appropriate.
- Consider whether there are ways to incorporate concepts of diminishing marginal returns or issues of relative versus absolute gain when evaluating changes in the number of accessible opportunities. This may be particularly relevant to the more sparsely populated rural areas, where gains in access achieved by projects can be smaller in magnitude but represent greater proportional gains relative to existing conditions when compared to similar changes in urban areas.

Network Availability and Performance. Network availability and performance determines (a) whether access is possible by a given mode, and (b) the "impedance" or effective resistance limiting access between the selected users and destinations of interest. Theoretically, impedance is a function of both the transportation network and the user of that network. Typical transportation performance variables like travel time, distance, and reliability, as well as direct costs like tolls/fares determine the barriers to access perceived by travelers. Depending on data availability and desired complexity, measures can be based on simple travel time measures, or on more aggregate metrics of generalized cost. User characteristics may also dictate the network options that are plausibly available. For example, an analysis of access for people without cars would be misleading if it based results on average drive times. Similarly, access for a firm that ships goods using a fleet of tractor-trailers may be concerned with where regulations or physical design issues prohibit passage of large trucks. These considerations, along with data availability and desired spatial/modal detail together determine the type of transportation network information used to calculate access. Finally, analysts must select a

69 Federal Highway Administration (2013)

70 For example: ICF International, SHRP2 Project C11: "Connectivity Analysis Tool: Technical Documentation and User's Guide," July 2013, Weblink.

specific functional form dictating how impedance is quantified in the access measure. Here, there are two common approaches:

1. Contour measures: Also called cumulative opportunity, isochronic, or threshold measures, the measures count all attraction activities within a defined threshold from the point of origin. Thresholds are selected with some behavioral basis by, for example, looking at the distribution of observed trip lengths for a particular type of travel. For example, an access to jobs measure (or access to workforce measure, from the firm perspective) might use thresholds in the range of 45—60 minutes, while a measure focused on freight market access would typically employ a much higher threshold value (e.g., three hours).[71] Thresholds may also be defined from the perspective of limits of acceptable access, as for example can be required by normative rules for access to public services. For example, a 2002 directive from the Ministries of Health Services and Health Planning in British Columbia, Canada sets minimum requirements of accessibility for access to acute health care including "Access will be provided to emergency services on a 24/7/52 basis within a one hour travel time for 98% of residents within the Region."[72]

2. Potential/gravity measures: These measures count all activities in an area of analysis, weighted by a function of impedance such that opportunities located further away are granted less weight than those close to the point of origin. The specific functional form of these measures dictates an implied tradeoff or equivalence between units of impedance and units of attraction (not necessarily one to one). The "effective density" measure used by the UK Department for Transport to evaluate productivity impact of transportation investments is one example of this type of measure, where employment is weighted by the inverse of a generalized cost measure, raised to the power of an industry-specific decay parameter.[73] Utility-based measures are a specific type of gravity measure developed through the estimation process used in travel modeling. They are based on observed behavior regarding how travelers choose destinations and include utility functions that capture traveler preferences. A detailed discussion of the functional forms of accessibility measures can be found in the work by Bhat et al. performed for FHWA at the University of Texas at Austin.[74]

There are also hybrid approaches of the above. For example, one might employ a gravity-type measure with a decay function but limit for both behavioral and practical reasons the search space for that function to a defined maximum impedance threshold. Similarly, one can approximate a gravity measure by adopting a series of weighted threshold measures (e.g., measuring access within 30, 40, and 50 minutes and then developing a composite measure that weights the inner value more than the outer ones).

Appalachia-Specific Considerations: The following are Appalachia-specific considerations for the definition of network availability/performance that should be further investigated through subsequent research:

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71 Alstadt, Weisbrod, and Cutler, 2012.

72 British Columbia Ministries of Health Services and Health Planning, "Standards of Accessibility and Guidelines for Provision of Sustainable Acute Care Services," 2002. Weblink.

73 Department for Transport, "TAG UNIT A2.4 Appraisal of Productivity Impacts," September 2016. Weblink.

74 Bhat C et al., "Urban Accessibility Index: Literature Review," 2000, Weblink. and Bhat C et al., "Development of an Urban Accessibility Index: Formulations, Aggregation, And Application," 2002, Weblink.

- Recognize different geographic scales (either through different thresholds or more/less steep decay functions) for different types of access.
- Consider investigating whether observed trip length distributions are meaningfully different in rural areas or in Appalachia specifically to understand whether thresholds/decay functions might need to be tailored to longer average trip lengths.
- Engage with decision-makers to investigate the relative interpretability and usability of threshold versus gravity measures.
- Consider the role of non-traditional mobility options for which transportation network performance data may be less available (i.e., TNCs, non-fixed-route transit/shuttle services).

Additional Access-Related Measurement Approaches

In addition to the more traditional type of access measures outlined above, there are other types of measures that may be of interest in Appalachia because they address access-related policy issues:

1. Supply-side measure of network/service density/coverage: This class of measures selects indicators of infrastructure or service supply (e.g., lane-miles, bus stops, TNC drivers) and then normalizes them by an explicit or implicit measure of the market served (e.g., per square mile or population base, or simply within a defined geography). For example, the United States Environmental Protection Agency's "Smart Location Database" has measures of the frequency of transit service per square mile as well as measures of intersection or network density.[75]

2. Measures of economic distress or disadvantage: ARC already tracks a range of measures used to benchmark economic status including unemployment and poverty rate. These and similar measures can be used independently or in conjunction with access measures to specifically target areas of disadvantage. Examples of this approach can be found in Chapter 2.2.

[75] Ramsey K. and Bell A., "Smart Location Database: Version 2.0 User Guide," 2014, Weblink.

The Spectrum of Qualitative versus Quantitative Measures

While the development of measures most typically means the use of quantitative metrics, it is important to remember that decision-support in practice is achieved through a range of approaches on a spectrum from qualitative to quantitative. Within investment prioritization, this can include:[76]

- Quantitative ratings
- Qualitative scoring (e.g., scoring of High/Medium/Low or from 0—10 based on decision rules or analyst judgement)
- Pass/Fail scoring (e.g., a decision rule that says if a certain threshold is passed, invest, or allocate points)

1.5 Tools and Data

Table 2 summarizes a range of available data sources for calculating access measures, along with citations. These sources will be further explored in Chapter 3.3.

Table 2. Data Sources to Measure Access

		Resolution		Availability	
Type	**Data Source**	**Zonal**	**Point**	**Public**	**Proprietary**
Origins/Destinations (locations and size of population, workforce, employment, hospitals, colleges, intermodal terminals, etc.)	United States Census[77]	X		X	
	Dun & Bradstreet[78]		X		X
	Info USA[79]		X		X
	ESRI[80]	X	X		X
	OpenStreetMap[81]	X	X	X	

[76] Stein, N., Weisbrod, G., Sieber, M, «NCHRP Synthesis 521. Investment Prioritization Methods for Low-Volume Roads," Weblink.

[77] https://www.census.gov/data.html.

[78] https://www.dnb.com.

[79] https://www.infousa.com.

[80] https://www.esri.com.

[81] https://wiki.openstreetmap.org/wiki/Map_Features.

		Availability	
Type	**Data Source**	**Public**	**Proprietary**
Network availability, conditions, and performance for highways, rail, bus, air, broadband, and pedestrian/bicycles.	State/Regional Travel Models	X	
	Oak Ridge National Labs (ORNL)[82]	X	
	National Performance Management Research Data Set (NPMRDS)[83]	X	
	HERE Data[84]		X
	INRIX[85]		X
	FHWA FAF Network Database[86]	X	
	ESRI Street Map[87]		X
	PC*MILER (Truck Routing)[88]		X
	OpenStreetMap[89]	X	
	General Transit Feed Specification (GTFS)[90]	X	
	Broadbandmap.fcc.gov	X	
		Availability	
Type	**Data Source**	**Public**	**Proprietary**
Accessibility and connectivity databases	Access across America[91]	X	
	EPA Smart Location Database[92]	X	
	AllTransit[93]	X	X
		Availability	
Type	**Example Data Source**	**Public**	**Proprietary**
Tools for calculating access measures	ESRI ARC GIS[94]		X
	QGIS[95]	X	X
	Sugar Access[96]		X
	State/Regional Travel Models	X	X

82 https://cta.ornl.gov/transnet/index.html.
83 https://ops.fhwa.dot.gov/freight/freight_analysis/perform_meas/vpds/npmrdsfaqs.htm.
84 https://www.here.com/.
85 http://inrix.com/.
86 https://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf4/netwkdbflow/index.htm.
87 https://www.esri.com/en-us/arcgis/products/streetmap-premium-for-arcgis/overview.
88 https://www.pcmiler.com/.
89 https://wiki.openstreetmap.org/wiki/Routing.
90 https://developers.google.com/transit/.
91 http://access.umn.edu/research/america/.
92 https://www.epa.gov/smartgrowth/smart-location-mapping.
93 https://www.cnt.org/tools/alltransit.
94 https://www.esri.com/en-us/arcgis/about-arcgis/overview.
95 https://www.qgis.org/en/site/.
96 http://www.citilabs.com/software/sugar/sugar-access/.

2 Accessibility Measurement: State of Practice

2.1 Overview

This chapter takes a close look at the state of practice in Appalachian states. Prioritization processes and criteria at state DOTs and how they reflect the conditions in the Appalachian Region are at the center of the review (Chapter 2.2). Additionally, we describe how states consider accessibility in their Long-range Transportation Plans (Chapter 2.3) and in their Performance Measures (Chapter 2.4).

Going beyond the state of practice in state transportation agencies, Chapter 2.5 also reviews other areas or processes in which accessibility metrics are in use within the state of practice, including for instance to assess spatial coverage in health care or education both in Appalachian state, regional or local agencies, and in other states or countries.

Chapter 2.6, finally, summarizes the findings and their implications for the subsequent Chapters.

This review draws from four sources of existing knowledge:

(1) *Documented practice in accessibility measurement and prioritization*,

(2) *Research and strategy documentation from the economic development community in Appalachia,*

(3) *Identified data and analytical resources,*

(4) *Interviews with representatives of federal, state, and regional/local agencies*

Throughout this review process, special attention has been paid to ensure the unique opportunities and challenges of Appalachia are identified and documented.

2.2 Accessibility Considerations in Prioritization of State Transportation Investments in Appalachia

State DOTs employ a range of prioritization practices to rank and select transportation projects. Prioritization processes can differ significantly across states, including variation in:

- Usage of quantitative versus qualitative criteria
- Their approach to subdividing their overall investments into programs or areas within which projects are ranked against one another
- The degree to which accessibility considerations are incorporated into the set of evaluation criteria, and the specific form of those measures

The following Chapters profile accessibility measurement within State DOT prioritization processes based on a review of published documentation for seven of the thirteen Appalachian states.

Virginia SMART SCALE[97]

Virginia's SMART SCALE scoring process incorporates multiple quantitative accessibility metrics, calculated using the Citilabs Sugar Access tool to evaluate access with and without a project.[98] The SMART SCALE process applies to two out of three of state's transportation funding programs: The District Grant Program (DGP) and the High-Priority Projects Program (HPPP), each of which accounts for 27.5% of funds. The remainder of the state's funding (45%) goes to the State of Good Repair Program (SGR) which is not subject to SMART SCALE. Regional entities (MPOs, PDCs), localities, and public transit agencies can submit SMART SCALE applications. Projects are scored centrally by a Technical Evaluation team with members from the Virginia Office of Intermodal Planning and Investment, the Virginia Department of Rail and Public Transportation, and Virginia DOT. SMART scale applies across modes to highway, transit, rail, bicycle, pedestrian, and transportation demand management projects.

Of the six factor areas included in SMART Scale, accessibility and related concepts appear in three of them: Accessibility, Economic Development, and Land Use (Figure 3).

Figure 3. Summary of SMART SCALE Evaluation Measures

Factor Areas	Measure ID	Measure Name	Measure Weight
Safety	S.1	Equivalent property damage only (EPDO) of Fatal and Injury Crashes*	50%
	S.2	EPDO Rate of Fatal and Injury Crashes	50%
Congestion Mitigation	C.1	Person Throughput	50%
	C.2	Person Hours of Delay	50%
Accessibility	A.1	Access to Jobs	60%
	A.2	Access to Jobs for Disadvantaged Persons	20%
	A.3	Access to Multimodal Choices	20%
Environmental Quality	E.1	Air Quality and Environmental Effect	50%
	E.2	Impact to Natural and Cultural Resources	50%
Economic Development	ED.1	Project Support for Economic Development	60%
	ED.2	Intermodal Access and Efficiency	20%
	ED.3	Travel Time Reliability	20%
Land Use	L.1	Transportation-Efficient Land Use	70%
	L.2	Increase in Transportation Efficient Land Use	30%

* 100% for Transit and Transportation Demand Management projects

Source: SMART SCALE Policy Guide

The *Access to Jobs (A.2)* and *Access to Jobs for Disadvantaged Persons (A.2)* measures are calculated using an accessibility measure with a travel time decay function where jobs within a shorter travel time are weighted more than jobs farther away. The decay function is based on travel survey data. The measures also incorporate a threshold in that the analysis does not consider jobs located beyond

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97 Commonwealth Transportation Board, "SMART SCALE Technical Guide," Weblink. and "SMART SCALE Policy Guide," Weblink.

98 Citilabs, "Sugar Access Helps State of Virginia Connect People with Jobs," Weblink.

45 minutes (or 60 minutes for transit). The analysis calculates accessibility with and without the improvement at the United States Census block group level (United States Census block for transit). Improvements are coded in the GIS accessibility tool based on the following:

- Cars/trucks–estimated change in congested roadway speed applied to the network
- Transit–new service coded into GTFS
- Non-motorized modes–coding of new/ improved pedestrian elements into network

For *A.1 Access to jobs*, the change in accessibility measure is weighted by total population, while for *A.2 Access to Jobs for Disadvantaged Persons* it is weighted by the low income, minority, or limited-English proficiency (LEP) population. Because workforce accessibility is based on the number of workers reached within the designated threshold rather than the percentage change in workers accessible, rural areas with fewer workers may tend to score lower compared to larger metro areas.[99]

The *A.3 Access to Multimodal Choices* measure allocates points based on a checklist of multimodal elements included in the project (transit, bike/ped, park and ride, etc.) and then weights this scoring based on the number of non-single-occupancy-vehicle-users.

Within the Economic Development factor area, *ED.2 Intermodal Access and Efficiency* also applies a rubric of points based on the level to which the proposed project (1) enhances access to existing or planned distribution centers, intermodal transfer facilities (excluding ports and airports), manufacturing industries or other freight intensive industries, (2) supports enhanced efficiency on a primary truck freight route, or (3) enhances access or reduces congestion at or adjacent to Virginia ports or airports. This point allocation is then weighted by total freight tonnage within the project corridor and by the total length of the proposed roadway project contributing to the operational benefit to freight movement.

The Land Use and Transportation Coordination measures are only applied in areas over 200,000 in population. The measures are designed to "determines the degree to which the project supports population and employment that on averages has a reduced impact on the transportation network."[100] Both *L.1 Transportation-Efficient Land Use* and *L.2 Increase in Transportation-Efficient Land Use* are based on calculations of non-work walk accessibility. These measures are calculated at the United States Census block level using a decay function and are applied for an area within a 3-mile buffer of each project. Analysis of changing accessibility is based on coded changes to the pedestrian network due to the project. Non-work destinations are weighted differently by type and assigned limits to the number of non-work destinations that are counted (reflecting a limit to the returns from additional accessible destinations), as shown in Figure 4. L.1 is calculated as the product of the post-project non-work accessibility value and the future (2025) count of total jobs and population within the three-mile buffer area. L.2, instead of weighting access by future job-population density, weights the access measure by the *difference* between future and existing job-population density.

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[99] Hodge, Dan, "Review of state DOT project prioritization methods and impact to Appalachia," March 26, 2018.

[100] Commonwealth Transportation Board. SMART SCALE Technical Guide.

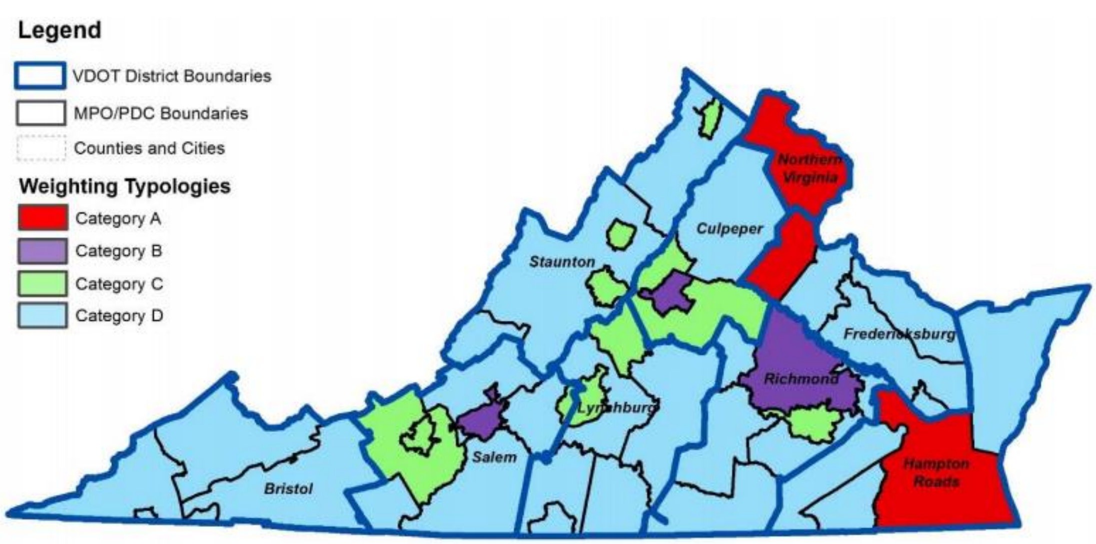
Figure 4. Local Non-Work Access Values in SMART SCALE

Destination Type	Definition (specific destinations included)	Points per destination
Bank	Bank, ATM	0.74 (up to 15 occurrences)
Education	School	5.6 (up to 2 occurrences)
Entertainment	Cinema, Performing Arts, Museum, Nightlife, Sports Complex, Convention/Exhibition Center, Sports Center, Animal Park	5.6 (up to 2 occurrences)
Food & Drink	Restaurants, Coffee Shop, Winery, Bar or Pub	0.25 (up to 45 occurrences)
Grocery	Grocery	3.7 (up to 3 occurrences)
Healthcare	Hospital, Medical Service, Pharmacy	3.7 (up to 3 occurrences)
Public Services	Library, Post Office, Community Center, City Hall, Court House, Police Station	3.7 (up to 3 occurrences)
Recreation	Golf Course, Ice Skating Rink, Campground, Park/Recreation Area	3.7 (up to 3 occurrences)
Shopping	Shopping, Convenience Store, Clothing Store, Department Store, Specialty Store, Home Improvement & Hardware Store, Office Supply & Service Store, Bookstore, Home Specialty Store, Sporting Goods Store, Consumer Electronic Store	0.34 (up to 33 occurrences)
Total points		**100**

Source: SMART SCALE Technical Guide.

Finally, the SMART SCALE process applies differential weighting of each high-level factor area as a function of regional area type, as shown in Figure 5 and Figure 6. This process is designed to reflect different regional needs across the state. For example, rural area projects (category D) give the highest weight to economic development factors (35%) and place less emphasis on congestion mitigation (10%). By contrast, large urban areas (category A) score economic development accounts at only 5% and congestion at a much higher 45%. Rural areas also heavily weight safety at 30%, compared to only 5% in the most urban areas. The accessibility factor area is given the most weight in Category B and C areas which are smaller urban areas.

Figure 5 SMART SCALE area type for weighting typologies



Source: SMART SCALE Policy Guide

Figure 6 SMART SCALE Weighting Typologies by Area Type

Factor	Congestion Mitigation	Economic Development	Accessibility	Safety	Environmental Quality	Land Use
Category A	45%	5%	15%	5%	10%	20%
Category B	15%	20%	25%	20%	10%	10%
Category C	15%	25%	25%	25%	10%	-
Category D	10%	35%	15%	30%	10%	-

Source: SMART SCALE Policy Guide

All measure values in the SMART SCALE analysis are normalized relative to the highest measure in the application set (i.e., the normalized measure value is the measure value as a percentage of the maximum measure value). The final SMART SCALE score is the Project Benefit (based on all the criteria and weighting) divided by the SMART SCALE Cost (not total cost).

North Carolina Prioritization 5.0[101]

The North Carolina Strategic Transportation Investments (STI) Law, signed in 2013, establishes a prioritization process for capital expenditures (including mobility/expansion and modernization projects) across all modes. The law groups funding into three overarching categories:

- Statewide mobility (40% of funds)–focuses on addressing significant congestion and bottlenecks, prioritized entirely based on state defined evaluation criteria
- Regional impact (30% of funds)–focuses on improving connectivity within regions, prioritized based on a combination of state defined criteria (70%) and local input (30%)
- Division needs (30% of funds)–focuses on addressing local needs, prioritized based on a combination of state defined criteria (50%) and local input (50%)

Local input includes input from metropolitan planning organizations, rural planning organizations, and the NCDOT divisions. The statewide mobility program includes coverage of the ADHS highway routes in addition to the interstates, NHS routes, and other major highways.

Table 3 summarizes the quantitative criteria applied by NCDOT to each mode and category. Highlighted in blue are those places where NCDOT employs access and related connectivity criteria. Note that these concepts are employed only for regional and local (division needs) projects, and are defined differentially across modes:

Highway Accessibility/Connectivity is a composite measure of two indicators. The first, the *County Economic Indicator*, allocates points on the basis of economic distress factors such as median household income and the unemployment rate. The second, *Improve Mobility*, applies only to projects that upgrade a highway's facility type (e.g., from a 2-lane to a multilane highway). Projects that qualify receive points based on travel time savings per user. Note that neither of these indicators are access measures in a conventional sense, but both address a purpose to "improve access to opportunity in rural and less-affluent areas and improve interconnectivity of the transportation network." NCDOT staff wish to implement a measure of jobs accessible within a defined travel time threshold but report not having the tools to accomplish this yet for

[101] NCDOT, "Strategic Mobility Fund," Weblink; NCDOT, "Prioritization 5.0 Master Presentation," Weblink.

the large number of projects that are evaluated statewide. The adopted criteria address the same goals given this limitation. The agency is investigating the possibility of incorporating network analysis in ARC GIS as well as the availability of 3rd party data sources/tools for access measures.[102]

Bicycle and Pedestrian Access and Connectivity. *Access* for bicycle and pedestrian projects is comprised of two indicators: *Destination Type* and *Distance to Prime Destination*. The first allocates points based on the type of destination(s) served by the project, with different levels of points allocated for major versus secondary centers. Major centers include destinations such as municipal centers (e.g., town hall or courthouse), transit stations, major employment centers, mixed commercial centers, university or colleges, and tourist destinations. Secondary centers include destinations such as minor employment centers, schools, and parks. The *Distance to Prime Destination* indicator is simply the distance from the project to the most significant identified destination. Overall, this scoring tends to reward projects that serve or are in close proximity to major trip generators that provide mode shift opportunities. Bicycle/pedestrian *connectivity* is a measure of the connectivity created by the project to existing bicycle and/or pedestrian facilities at each endpoint, stratified by the quality of the infrastructure. The measure rewards projects that expand pedestrian/bicycle networks more so that those that build unconnected new corridors.

Table 3. Summary of Quantitative Criteria by Category and Mode–NCDOT P5.0

Mode	Statewide Mobility	Regional Impact	Division Needs
Highway	Congestion 30% Benefit-Cost 25% Freight 25% Safety 10% Economic Comp. 10%	Congestion 20% Benefit-Cost 20% Safety 10% Accessibility/Connectivity 10% Freight 10%	Congestion 15% Benefit-Cost 15% Safety 10% Accessibility/Connectivity 5% Freight 5%
Aviation	NCDOA Rating 40% FAA Rating 10% Local Contribution 30% Benefit/Cost 20%	NCDOA Rating 30% FAA Rating 5% Local Contribution 20% Benefit/Cost 15%	NCDOA Rating 25% FAA Rating 10% Local Contribution 5% Benefit/Cost 10%
Bicycle and Pedestrian	Not Eligible		Safety 15% Access 10% Demand/Density 10% Connectivity 10% Cost Effectiveness 5%
Ferry	Not Eligible	Asset Condition 15% Benefits 10% Accessibility/Connectivity 10% Asset Efficiency 15% Capacity/Congestion 20%	Asset Condition 15% Benefits 10% Accessibility/Connectivity 10% Asset Efficiency 15%
Public Transp.	Not Eligible	Impact 15% Demand/Density 20% Efficiency 10% Cost Effectiveness 25%	Impact 10% Demand/Density 10% Efficiency 10% Cost Effectiveness 20%
Rail	Benefit-Cost 35% System Opportunities 15% Safety 30% Capacity and Diversion 10% Economic Comp. 10%	Benefit-Cost 25% System Opportunities 10% Safety 15% Capacity and Diversion 10% Economic Comp. 10%	Benefit-Cost 10% System Opportunities 15% Safety 10% Capacity and Diversion 10% Economic Comp. 5%

[102] Interview with Jason Schronce and David Wasserman, NCDOT. December 20, 2018.

Ferry Accessibility/Connectivity assesses the degree to which ferry routes connect people to identified points of interest within concentric rings (10, 20, and 30 miles) that are weighted based on a distance decay (75% for Ring 1, 50% for Ring 2, 25% for Ring 3). Points of interest (such as job or service centers) are identified collaboratively by NCDOT and the NC Department of Commerce.

Rail System Opportunities. This criterion includes an *accessibility/connectivity score* and a *multimodal score*. The *accessibility/connectivity score* is differentiated by type of project. Passenger stations are given a score equal to the ratio between the number points of interest (POIs) within 10 miles of a new proposed station and the average number of POIs within the same distance of existing state-supported stations. Freight rail improvements are scored as the percentage of a project that improves the NC Transportation Network (NCTN) statewide rail system. Grade crossing projects receive a score calculated at the ratio between employment density within 1 mile of the grade crossing and overall employment density within one mile of rail line inside the county. The *multimodal score* allocates points using a rubric that qualitatively defines potential benefit to other modes based on the relative degree of interaction between rail and other modes.

In addition to the above statewide criteria, individual regional organizations define their own local input ranking criteria. For example, High Country Rural Planning Organization (RPO), an ARC LDD, allocates access and connectivity points to highway, bicycle, and pedestrian projects within its own scoring process. Highway projects are granted points if they provide direct or indirect access to educational, health care, emergency service, or employment facilities. Bicycle and pedestrian projects are similarly rewarded if they provide access to a school, medical center, shopping center, residential development, or major employment center or if they provide connection to existing bike or pedestrian facilities.[103] The Piedmont Triad RPO, also in Appalachia, allocates points to a project if it improves access to airports, freight distribution facilities, major commercial/industrial districts or freight access to regional and national economic centers. Staff also allocate points to a project if it improves access to existing employment centers or opens access to land zoned, or identified in development guides, for future employment.[104] These determinations are made qualitatively based on a review of available GIS/maps information.

Ohio TRAC Prioritization[105]

The Ohio Transportation Review Advisor Council (TRAC) oversees project prioritization and selection for major new transportation capacity projects that cost more than $12 million. Prioritization criteria for this program are grouped into four areas: Transportation factors (55 points available), economic performance factors (15 points available), local investments (15 points available), and project funding plans (15 points available). While there are no criteria explicitly defined with terms such as “access” or “accessibility” in the TRAC prioritization, the criteria shown in Table 4 address related objectives of relevance to Appalachia including support for strategic transportation connections, targeting investment to areas of economic distress, and leveraging local investment to support economic development.

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[103] High Country Rural Planning Organization (RPO), “2017-2018 STIP Project Solicitation and Ranking Methodology,” Weblink.

[104] Piedmont Triad Rural Planning Organization “Prioritization Policy,” Weblink.

[105] Ohio DOT, “TRAC Policy & Procedures,” Weblink.

Table 4. Ohio TRAC Criteria that Address Issues of Relevance to Appalachia

Area	Relevant Criteria	Description
Transportation	Strategic Transportation Systems Connections (max 5 / 55 points)	• Projects that are part of an STS Corridor–2 points • Projects that connect two or more STS corridors or intermodal hubs–2 points • Project that connect an STS resource with a local freight or transit resource–1 point
Economic Performance	Economic Distress (max 2.5/15 points)	• Up to 2.5 Points awarded based on unemployment and poverty rates relative to state average • Up to an additional 2.5 for projects that create jobs/increase GSP in areas of economic distress
Local Investment	Multiple measures (15 points available)	• Points allocated based on the ratio of existing built-out local investment as well as committed investment within the next 5 years, relative to total project cost • Local investment includes things such as local street/water/sewer/electricity provision, square feet of development, etc. • Used to grant more points to projects that leverage local investments

Kentucky SHIFT

Kentucky's SHIFT (Strategic Highway Investment Formula for Tomorrow) process is used to guide prioritization of projects in the State Highway Plan. It applies to safety improvements, road widening, reconstruction, new routes and interchanges but excludes the rural and municipal aid system, maintenance work, federally dedicated projects, and MPO dedicated projects.[106] Projects are scored in two groups—statewide and regional—across five key attributes–safety, congestion, asset management, economic growth and benefit/cost. Economic growth accounts for 20% of the overall score for statewide projects and 15% for regional projects. For statewide projects, this score is comprised of 10% economic competitiveness and 10% freight where economic competitiveness is evaluated based on estimates of jobs and value created, as calculated in TREDIS, and freight is a function of truck volumes, Kentucky Highway Freight Network tier, and truck reliability. For regional projects, economic growth is made up of 5% freight (as defined above) and 10% based on an "accessibility/connectivity" measure designed to capture how likely the project is to impact rural areas under the most distress. The accessibility/connectivity measure is a function of traffic volumes and county "need tiers" that reflect factors such as poverty, unemployment, wages, level of education, and population change.[107, 108]

106 KYTC, "SHIFT KENTUCKY AHEAD Strategic Highway Investment Formula for Tomorrow," Weblink.

107 KYTC, "Strategic Highway Investment Formula for Tomorrow: Formulas," Weblink.

108 KYTC, "SHIFT 2020 Formulas," provided by Amanda Spencer, KYTC Director of Planning.

KYTC is currently investigating ways to implement more formal accessibility measurement. While the existing accessibility/connectivity measure in SHIFT proxies for expected gains in distressed areas from improved access, the demographics-based approach is not viewed as ideal. Specifically, KYTC is conducting an accessibility/connectivity pilot project in one urban and one rural highway district. As part of the study, KYTC is using the Kentucky Statewide Travel Demand Model (KYSTM) to measure baseline accessibility from each county seat and additional households and jobs accessible from proposed network improvements within 40 and 90–minute travel time contour bands. KYTC views the longer travel time threshold as more appropriate for rural areas. In subsequent studies, KYTC expects to explore the differential impacts of improvements to alternate highway corridors on accessibility. While ultimately KYTC is interested in using accessibility metrics in prioritization, this will depend in part on the ability of the agency to implement a uniform and manageable process statewide. The pilot study also involved improvements to the KYSTM, specifically refinement of Traffic Analysis Zones (TAZs) and the spatial allocation of future growth, in order to provide more accurate accessibility analysis.[109]

Tennessee Prioritization of Highway Capacity Projects

Tennessee DOT has a project selection process that is applied as part of TDOT's 3–Year Work Program using an internal project evaluation system.[110] TDOT evaluates highway capacity projects using six performance criteria and project cost as shown in Figure 7. All projects are evaluated by considering the scoring (from the first 6 criteria) compared to project cost.[111]

In Appalachia, project scores tend to be highest in the categories of safety, economic development, and local input. Although none of these criteria directly address accessibility, economic development and local input provide related perspectives. The economic development criterion incorporates ARC's definition of economic distress.

While quantitative rating is used to support prioritization, the department also takes into account the goal of achieving geographic and urban-rural balance across the state when selecting projects.[112]

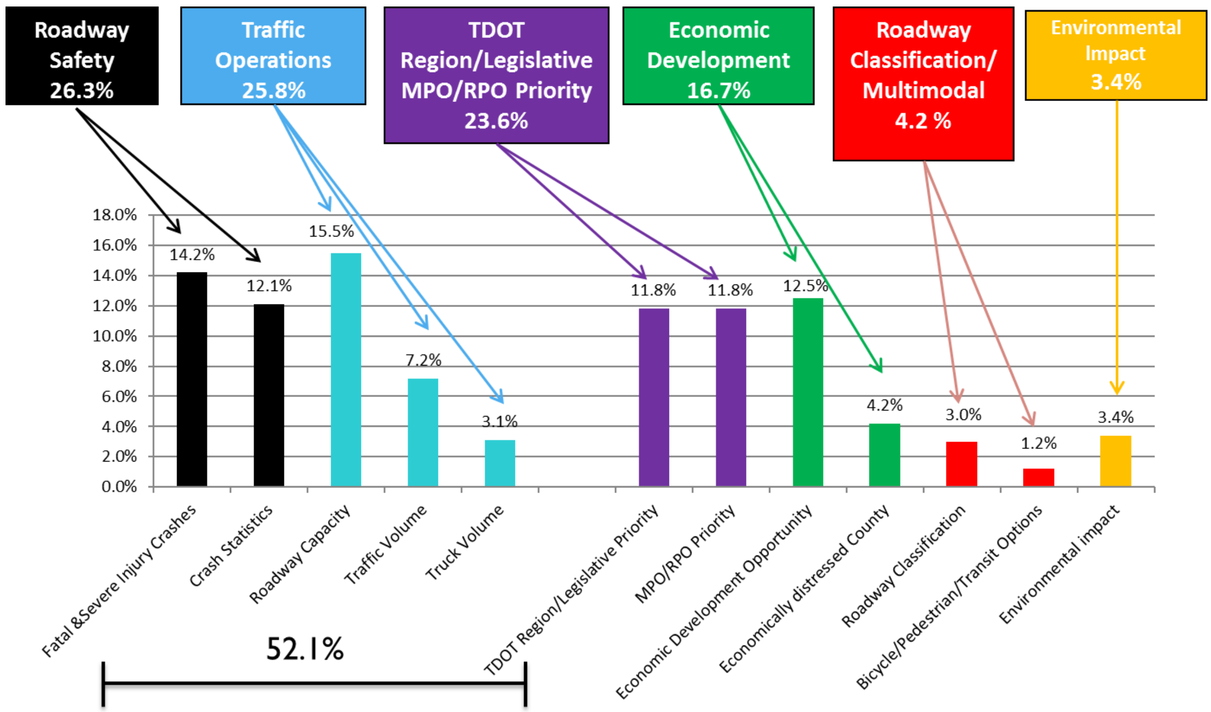
[109] Interview with John Moore, KYTC, December 19, 2018, and information provided by Amanda Spencer, KYTC, via email.

[110] TDOT, "TDOT 25-Year Long-Range Transportation Policy Plan: Plan Development," Weblink.

[111] Hodge, Dan, "Review of state DOT project prioritization methods and impact to Appalachia," March 26, 2018.

[112] Interview with Paul Degges, TDOT, December 21, 2018.

Figure 7 TDOT Criteria Weighting



Source: TDOT. Prioritizing TDOT's Candidate Projects (Presentation).

West Virginia and Pennsylvania

West Virginia has a recommended prioritization approach outlined in its most recent (but now dated) 2010 Multi-Modal Statewide Transportation Plan that does not explicitly address access.[113] However, the department is also currently engaged in a performance-based planning effort, within which WVDOT is looking to upgrade their PROVIS project mapping application to incorporate prioritization in the next LRTP Update.[114] Similarly, Pennsylvania's 2016 LRTP highlights a new prioritization framework/tool that was recently developed.[115] However, the methodology is not at present published.

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[113] WVDOT "West Virginia Multi-Modal Statewide Transportation Plan," Weblink.

[114] Inglis-Smith, C., Elsayed, G., and Sloan, Barb, "Collecting and Managing Data for Performance-Based Planning," Weblink.

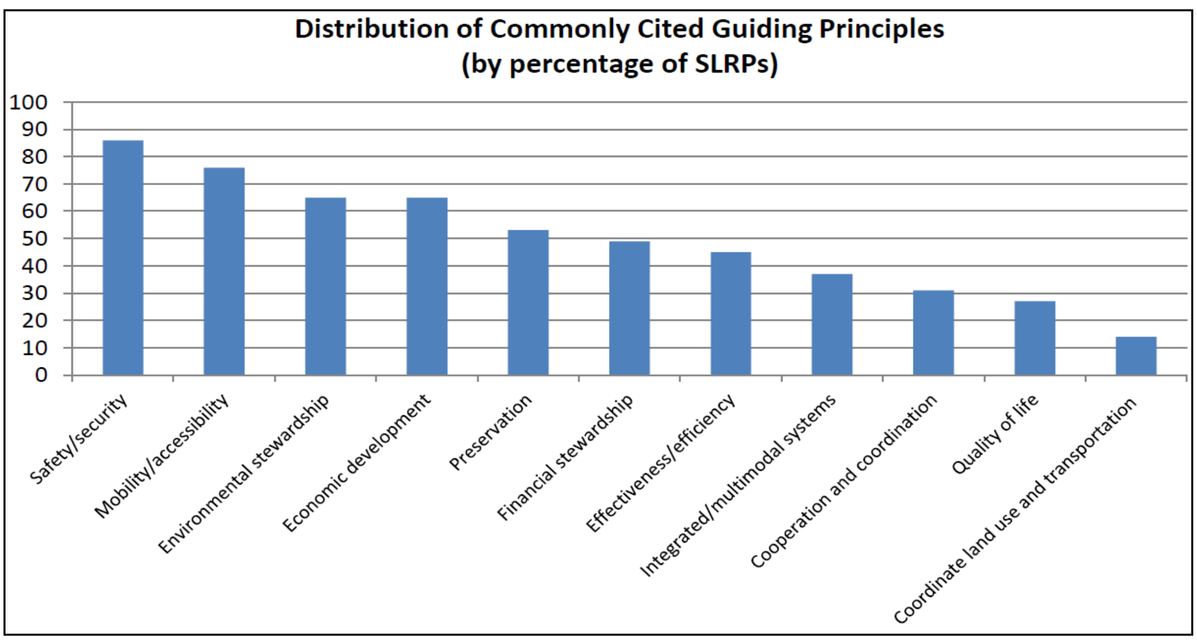
[115] PennDOT, "PA On Track: PA's Long Range Transportation & Comprehensive Freight Movement Plan," Weblink.

2.3 Accessibility Considerations in Long-Range Transportation Plans

The federal government requires each state to prepare a long-range transportation plan (LRTP) that provides for the development and implementation of its multimodal transportation system over a roughly 20-year planning horizon. There is great diversity in the approach that State Departments of Transportation take to their LRTPs, the Fixing America's Surface Transportation (FAST) Act and implementing regulations require that these plans address ten specific factors.[116] Among these factors is accessibility. As such, accessibility is a major component of the policies, goals, and visions that states articulate in their LRTPs as they seek to guide decision making and project prioritization.

In 2012, the USDOT Volpe Center conducted a review of the long-range plans of all 51 state DOTs (including DC) and found that 3/4 of them included "mobility and accessibility" as a goal (see Figure 8).[117] A 2018 scan of state DOT long range plans by staff of EDR Group (now EBP) has confirmed that the prevalence of mobility and accessibility goals still holds today. Examples include Mississippi, Kentucky, Virginia, Montana, Pennsylvania, California, and Washington State. A typical example of a goal definition is Virginia's Vtrans 2040 Vision Plan; it defines the accessibility goal as follows: *"Accessible and Connected Places–increase the opportunities for people and businesses to efficiently access jobs, services, activity centers, and distribution hubs."*

Figure 8 Role of Accessibility among the Guiding Principles of LRTPs



Source: Volpe Transportation Systems Center, "Trends in Statewide Long-Range Transportation Plans," USDOT, 2012.

116 United States Department of Transportation, Federal Highway Administration (2017), Trends in Statewide Long-Range Transportation Plans: Core and Emerging Topics in 2017 URL: https://www.fhwa.dot.gov/planning/processes/statewide/practices/slrtp/fhwahep18003.pdf.

117 Volpe Transportation Systems Center, "Trends in Statewide Long-Range Transportation Plans," USDOT, 2012.

One of the six goals listed in the Ohio LRTP "Access Ohio 2040" vision relates to accessibility and connectivity, aiming to "increase customer access to Ohio's multimodal transportation system and improve linkages between modes."[118] The plan acknowledges that access to the transportation system means access to critical amenities like job, schools, and healthcare. As such, ODOT used the long-range planning process to analyze the impact of its anticipated 2040 transportation network on accessibility, particularly for environmental justice populations. After identifying concentrations of EJ populations in 3,600 statewide analysis areas (based on ethnicity and income), ODOT estimated changes in access for each analysis area to ensure that the benefits of its plan were equitable across EJ and non-EJ populations.

California's LRTP is another example of a plan with a strong emphasis on accessibility, which is included in the plan's overarching vision for 2040.[119] As part of the plan's vision, the LRTP focuses on six core goals, of which one is to "improve multimodal mobility and accessibility for all people." The California plan points to the role of the state transportation network in providing access to education, healthcare, jobs, recreational activities, and other goods and services. Furthermore, the plan notes that inadequate access to transportation can negatively affect health, particularly for vulnerable populations. In contrast, the plan notes that a fully accessible transportation system promotes health and allows for easy travel to supermarkets and opportunities for exercise through active transportation.

As a concept, State DOTs also acknowledge the importance of accessibility to a vibrant economy, particularly by enabling commuting and freight movement. For example, California's LRTP calls on the transportation network to provide greater access to destinations as it allows goods to flow to market. Similarly, Ohio's plan directly connects its accessibility and connectivity goal to a performance management focus area on freight movement.

2.4 Accessibility Considerations in Sets of Performance Measures

Performance Measures are used by most state DOTs to track progress relating to goals. Yet, while most Statewide LRTPs include mobility and accessibility as a goal, the associated performance measures of nearly all states concentrate on mobility–typically covering mobility choice (most often measured via transit availability or ridership) and traffic movement (most often measured via travel times on key travel corridors). Very few states currently include accessibility as an ongoing statewide performance measure, a situation that can be attributed to a lack of readily available in-house data, knowledge and/or resources to measure it.

[118] Ohio Department of Transportation (2014), Access Ohio 2040. URL: http://www.dot.state.oh.us/Divisions/Planning/SPR/StatewidePlanning/access.ohio/AO40_library/ODOTAccessOhio2014.pdf.

[119] California Department of Transportation (2016), California Transportation Plan 2040: Integrating California's Transportation Future. URL: http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/Final%20CTP/FINALCTP2040-Report-WebReady.pdf.

There are two notable examples of best practice. California's SLRTP report notes performance measures covering both (a) travel time from home to work and (b) the percentage of the population located within one-quarter to one-half mile of a transit station/stop or bus corridor. While the CTP2040 report shows the home to work access measure in terms of mean travel time, other California DOT reports indicate that they also track the percentage of workers whose homes are within 15, 30, 45, and 60 minutes of their jobs. Virginia's Vtrans 2040 Plan has accessibility performance goals that parallel the California measures: (a) reduce average peak-period travel times on key corridors and (b) increase the accessibility to jobs via transit, walking and driving in metropolitan areas. Virginia applies its SMART SCALE measures to track progress relating to these goals.

2.5 Topic-Specific Accessibility Considerations in Appalachia

In addition to the use of access measures in state transportation prioritization described above, access measures and concepts also appear in a range of other evaluation and planning contexts in Appalachia. These are described by type below.

Access to Jobs and Markets

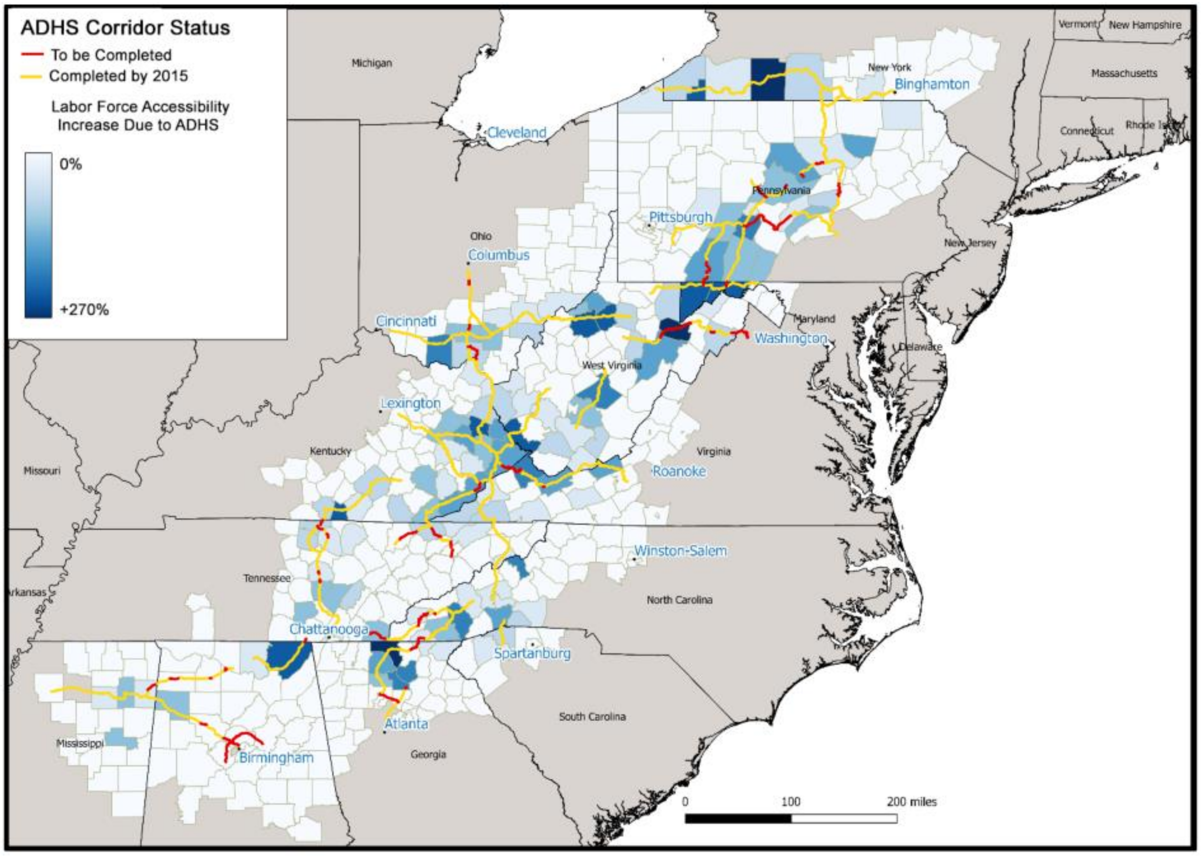
Access to jobs and markets has long been of interest to ARC, and there is a prior practice of evaluation from which to build. In an ARC study of access across all of Appalachia, a Network Appalachia Access measure was developed that considered proximity to transportation link and nodes including Interstate Highway interchanges, the ADHS/National Highway and intermodal facilities like rail terminals or ports. The conclusion of the study was that the access to domestic and international markets was in reach and that "Appalachia's economic success in the 21st century will depend on reliable, safe, and cost-efficient access" to those markets.[120]

Another recent study for ARC found that the Appalachian Development Highway System (ADHS) substantially improved accessibility overall, but not everywhere to the same extent. A 60-minute threshold was used for the purposes of the economic analysis of the ADHS to compare changes in workforce access among locations (Figure 9). Counties that have seen investments in the ADHS have experienced nearly twice the improvement in workforce access and grown 20% more than other counties.[121]

[120] Appalachian Regional Commission / Network Appalachia, "Access to Global Opportunity," N.d., Weblink.

[121] Appalachian Regional Commission, "Economic Analysis of Completing the Appalachian Development Highway System: Technical Report," EDR Group / WSP Parsons Brinckerhoff, July 2017, Weblink.

Figure 9. Example of Labor Force Accessibility Increase Mapping for Appalachia (ARC 2017)



Source: ARC

The same study looked also at supplier and delivery market access, making use of a 240-minute (4-hour) threshold to show differences in the extent to which the ADHS changed market access of businesses. In this case, business access was measured using employment as the indicator of supplier and delivery market opportunities.

A review of grant programs for economic development in the 13 Appalachian states reveals that some mention the improvement of access as a criterion for the project selection. However, none of them appear to have a documented measure to assess the extent to which a transportation infrastructure project will improve accessibility. Virginia, for example, names in its Economic Growth and Diversification Plan Evaluation Criteria two criteria related to accessibility: "Efforts to enhance access to higher paying jobs" and "workforce availability and gaps."[122] From publicly available documents it is not clear whether these criteria are assessed qualitatively or quantitatively. The Region 2 Planning and Development Council in southwestern West Virginia ranks economic development investments using a qualitative scoring system that allocates points based on whether or not project is in an economically distressed county and the scale of the population served by the new project, alongside other economic criteria such as job creation and economic diversification. It does not explicitly address access.[123]

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122 Commonwealth of Virginia, "Economic Growth and Diversification Plan Evaluation Criteria," Weblink.

123 KYOVA Region 2 PDC Project Evaluation Ranking Form. [internal use only, not to be shared].

Access to Education

More than half of Appalachia's workforce, 54.7%, holds only a high school diploma. The percentage of people with a bachelor's or higher degree (22.6%) is 7.2 percentage points lower than the national average.[124]

In the state of practice within education, measurement tends to focus on educational attainment or level of enrollment, rather than on the transportation or distance determinants of these outcomes. Nevertheless, as discussed in the prior Chapter, educational institutions are sometimes included in access measures developed by transportation planners.

Access to Health Care

A first step to help improve access to health care services across the Appalachian Region can be to analyze disparities. ARC did this by developing the Healthcare Cost, Coverage, and Access Index (HCCA). Each component is captured individually. Access is measured by ratios of physicians, dentists, or hospital beds per 100,000 residents and not by transportation-related metrics.[125] One study mapped dentist densities in Ohio on a county-level. Appalachian rural counties appear to have about one-half the dentist-to-population ratio of metropolitan counties.[126] The United States Department of Health and Human Services has adopted the provider to population ratio for the designation of Health Professional Shortage Areas (HPSA) for primary care, dental health and mental health. Additional common criteria are percentage of the population below Federal Poverty Level (FPL) and travel time to the nearest source of care outside the HPSA designation.[127] The Department's Index of Medical Underservice (IMU) combines four indicators: provider to population ratio, percentage population under poverty level, population age 65 and over and infant mortality rate.[128]

Transportation-related measures can be found in other sources. Given that the survival rate of patients with severe injuries is 25% higher with treatment in a level 1 Trauma Center, the Health Research and Educational Trust evaluated health access by measuring the share of the population that can reach a level 1 or 2 Trauma Center within one hour (85% of the total United States population, only 24% of the rural population). This measure is specifically relevant for Emergency Medical Services (EMS).[129]

One study analyzes different ways to measure the coverage of parts of the Appalachian Region by primary care providers. One of them is the provider to population ratio, the second the travel times from all Census block groups to the closest provider with a maximum travel time of 60 minutes. The

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[124] The Appalachian Higher Education Network, "Opening Doors, Changing Futures," 2011–2016.

[125] Appalachian Regional Commission, "Health Care Costs and Access Disparities in Appalachia," January 2012.

[126] Susi, L., Mascarenhas, A.K., "Using a geographical information system to map the distribution of dentists in Ohio," The Journal of the American Dental Association, May 2002.

[127] Department of Health and Human Services, Shortage Areas, web-content, accessed 12/28/2018.

[128] Department of Health and Human Services, Medically Underserved Area/Population (MUA/P), web-content, accessed 12/28/2018.

[129] National Academy of Sciences, "Emergency Medical Services: At the Crossroads," The National Academies Press, 2007.

third method developed "Two-Step Floating Catchment Areas" (2SFCA) for each provider. The maximum catchment was set to 60 minutes of travel time. Ten different spatial access scores were tested, among them some with various decay functions. The authors suggest using Spatial Access Ratio (SPAR) techniques, in which the choice of the decay function has less influence, when it is not immediately clear how far people in a given study region travel and what their travel preferences are.[130]

Some counties improve physical access to health care services by providing transportation services. Kentucky's Wayne and McCreary counties run scheduled vans to health and social facilities. Other counties rely on churches, volunteer organizations, and senior centers.[131] Calvert Health Medical Center in Calvert County, MD, has introduced a mobile health center. Denver Health, Denver, CO, has started a partnership with Lyft to provide rides for patients. And Grace Cottage Family Health and Hospital in Townshend, VT, collaborates with a nonprofit to run a volunteer driver program.[132] The states also receive $3 billion yearly to provide transportation for Medicaid patients, referred to as Non-emergency Medical Transportation (NEMT). [133] Overall, the reliance on non-traditional mobility options introduces complexity into any effort to measure transportation access to health care, as data availability about level of service is far less uniform or complete.

Community Health Centers fill gaps in rural areas, where high needs encounter low densities of practitioners. However, 43% of federally designated underserved areas do not have a community health center.[134] Telehealth is expected to help fill gaps wherever access to broadband is available. Additionally, the American Hospital Association (AHA) suggests that hospitals better align their inpatient and outpatient resources to the actual demand, which could help improve access to hospitals for rural communities.

While a few metrics to measure accessibility can be found in research and statistical analysis, it is not always clear that such metrics are used in the decision-making process. State Health Plans of the 13 states do mention the transportation constraints in rural areas and set goals to overcome them, but it is not clear from publicly available documents that this would be monitored through metrics. However, there are examples of quantitative accessibility metrics being used within overall planning evaluations. The Centers for Disease Control and Prevention (CDC) defines Community Health Assessments (CHAs) and Community Health Improvement Plans (CHIPs) as a best practice tool supporting public health.[135] In Virginia, CHAs and CHIPs are conducted by regional health districts at the county level with the support of the Virginia Department of Health and participation of a broad base of community partners. For example, staff from the Roanoke Valley-Alleghany Regional Commission are currently participating in a CHA for Botetourt County. To support the evaluation and planning, participants review a wide range of statistics related to public health determinants and

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130 Donohoe, J. et al., "Spatial Access to Primary Care Providers in Appalachia: Evaluating Current Methodology," Journal of Primary Care & Community Health, 2016.

131 Appalachian Regional Commission: "Exploring Bright Spots in Appalachian Health: Case Studies," July 2018.

132 Health Research & Educational Trust, "Social determinants of health series: Transportation and the role of hospitals," November 2017.

133 National Conference of State Legislatures, "Non-Emergency Medical Transportation: A Vital Lifeline for a Healthy Community," 1/7/2015, web-content, accessed 12/05/2018.

134 Government Accountability Office, web-content, accessed 12/05/2018.

135 CDC, "Public Health Systems & Best Practices," Weblink.

outcomes. One of the data sources used is the Virginia Health Opportunity Index. The HOI is composed of 13 indicators chosen based on a review of literature on the Social Determinants of Health (SDOH). Using "spatially-weighted regression techniques", researchers have found that "the HOI explains close to 60% of variation in Disability Free Life Expectancy (Healthy Life) in Virginia's Census Tracts."[136] Among those indicators are a number of measures of accessibility including:[137]

- Employment accessibility–measured as the number of jobs accessible, weighted by a travel time decay function
- Food accessibility– "Low access was measured as living far from a supermarket, where 1 mile was used in urban areas and 10 miles was used in rural areas to demarcate those who are far from a supermarket."
- Access to health care–Primary Care Physician FTEs within 30 miles.

Community Health Assessments can also involve surveys asking residents about barriers to health care access. In the case of Botetourt County, 67.43% reported that they had adequate access, while the other 32.57% cited a variety of barriers, the most common of which (14.57%) was health care cost. Transportation factors we reported, but at a lower level with 7.14% of survey respondents describing office location as a barrier to getting health care and 2.86% citing no transportation as the barrier to accessing needed care.[138]

Access to Broadband

The Federal Communications Commission has mapped the relationship between broadband access and health in America using different measures and combines them with each other, like rural broadband coverage (in percent) and physician density (per 100,000 population).[139] More specifically for Appalachia, Community Networks develops maps and toolkits for communities in the Region.[140]

2.6 Implications for the Definition and Methodology of Access

There is a generally a rich body of research about accessibility and its different characteristics and consequences. The research is motivated by a desire to support economic prosperity and quality of life. Moreover, while access issues have long been recognized in the state of practice by both transportation and economic development professionals as being important, accessibility is increasingly being addressed in a more systematic or quantitative manner within planning and prioritization.

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136 Virginia Department of Health, "Virginia Health Opportunity Index: Methodology," Weblink.

137 Anson-Dwamena, R., J. Crow, and A. Riggan, "The Health Opportunity Index; Version 2 (2015)—A Methodological, Analytical and Policy Perspective," Weblink.

138 Botetourt Community Health Assessment Questionnaire, July 11, 2018.

139 Federal Communications Commission, web-content, accessed 12/05/2018.

140 Institute for Local Self-Reliance, Community Networks, web-content, accessed 12/06/2018.

People's well-being and prosperity and their ability to thrive in rural areas of the Appalachian Region is a function of their ability to access jobs, education (which provides workforce skills), and health care, among other things. Looking beyond transportation, access to broadband internet appears increasingly to be a prerequisite for access to digital solutions—such as telework, teleeducation, and telehealth—that may compensate for a lack of physical access.

Additionally, businesses depend on accessibility in various ways. To remain located in Appalachia or to choose a location in the Region, businesses must be provided a decent accessibility to labor markets (workers with the right skills), to the supply chain (business to business) and to consumer markets and intermodal facilities (access to freight rail terminals, marine ports, and airports).

While all these various factors are broadly recognized as being important, the level to which they are addressed in a quantitative fashion varies considerably. Too often, measurement of accessibility is reduced to access of workers to jobs. Job access is the most commonly used kind of accessibility to describe how urban patterns and transportation networks interact and how this interaction changes over time or as the consequence of improvements in the transportation network. One reason for this may be the availability of data.

There is also a body of work that addresses health care access from a qualitative and access-oriented perspective, in large part driven by the desire of health care providers to understand their markets. However, while there is a lot of attention on access to different kinds of health care facilities, transportation access to education does not get the same level of attention. Measurement tends to focus on educational attainment or level of enrollment, rather than on the transportation or distance determinants of these outcomes. This is one gap that might be addressed in this research.

Another gap in the state of both research and practice is that most approaches to accessibility do not differentiate between urban, suburban, and rural conditions. Not all research studies or accessibility measures recognize the specific relevance and nature of accessibility in rural areas. Besides more general understandings of accessibility, the specific requirements in rural Appalachia have to be kept in mind in every step of the subsequent work. This may mean for example that the availability of a car has an even higher relevance than in urban or suburban areas, since in many cases no alternatives to cars are available in rural Appalachia. While only a relatively small share of households does not have cars, the accessibility burdens they face are particularly severe and likely merit special consideration.

The unique realities of rural Appalachia also point to specific measurement considerations in the subsequent Chapters of this report, as outlined below.

Measurement

When developing certain accessibility measures for Appalachia, it may be more appropriate to focus on measuring ease of access to one specific destination (employment center, population center, intermodal facilities, college, trauma center etc.), rather than assessing access to multiple destinations of the same kind. While some kinds of access are of the type where "more is better"–such as access to jobs, other types of access may be more about reaching a certain baseline of sufficiency. Measurement should try to reflect this distinction.

Because Appalachia is sparsely populated, it may be appropriate to adjust measures to account for the population or employment affected. Similarly, because rural residents tend to travel longer to access jobs and other amenities, longer travel time thresholds or less steep decay functions may be appropriate in rural areas, compared to urban areas. Given the low initial levels of access in Appalachia, when evaluating projects, it may be important to consider not only absolute differences, i.e., change in total jobs accessible due to an improvement, but also the percent change in accessibility caused by a project.

Given the sparseness of the transportation network and/or transportation service availability in Appalachia, measures that focus on network access (i.e., travel time to interstate interchange) or transportation service provision (e.g., availability of TNC services) may be appropriate even though they are in effect “proxies” for the greater access to destinations provided by those transportation system components

To support easy and consistent comparisons across the large multi-state Appalachian Region, analysts should consider using standardized units of geography for at least some of its selected access measures.

ARC already tracks measures of economic disadvantage. These can be used in conjunction with access measures to specifically target areas of disadvantage.

3 Definitions and Methodology

3.1 Overview

This Chapter documents the development of accessibility definitions for Appalachia and their methodologies. It is rooted in the review of research and practice shown in Chapters 1 and 2. Those summarize and structure the kinds of accessibility that are discussed in research or for which the practice in Appalachia has adopted metrics. Interviews with representatives of federal, state, and local agencies were conducted to learn about additional research and practical approaches as well as about the specific needs for accessibility metrics in Appalachia. Appendix I contains the list of the officials and representatives, with whom the 14 interviews were conducted, and the interview guide.

The needs for accessibility metrics in Appalachia are explored in Chapter 3.2. The interviewees' views on what they consider the most relevant kinds of accessibility for Appalachia are reported. This leads to the suggestions for kinds of accessibility to be considered in this study.

In Chapter 3.3, we explore the potential sources for data that can be used to develop metrics for the identified kinds of accessibility, which are subjects of this study. We distinguish between three kinds of data: population and employment data, other destination data (as for example regarding colleges, trauma centers etc.) and network data.

The methodological questions of measuring accessibility are covered in Chapter 3.4. They are structured along the two distinct parts of any accessibility metrics: how are we measuring the importance of a destination and which different options are there to measure the impedance to get to a given destination.

Chapter 3.5 summarizes our suggestion for the core set of metrics, any complementary metrics, the most appropriate methodologies to measure each of the metrics, and the necessary data to implement these metrics.

3.2 Accessibility Needs in Appalachia

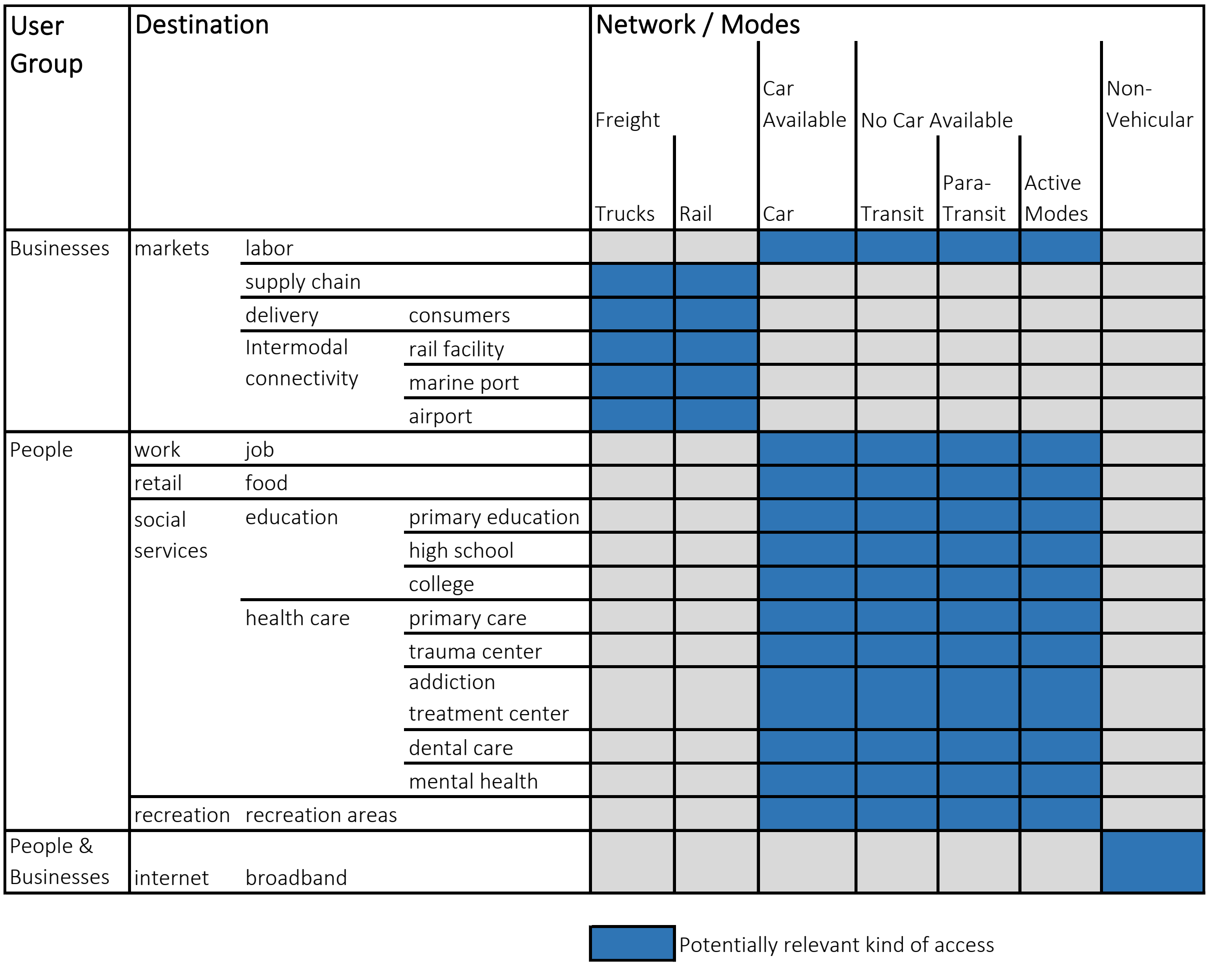
Needs Revealed from Existing Studies–Overview

As described in Chapter 1.4, we understand accessibility as being composed of three dimensions:

1. User Group (Access for whom? / from where?)
2. Destinations/Attractions (Access to where/what? How attractive?)
3. Network Availability and Performance (Are connections available? At what cost and along which network?)

We include the kinds of accessibility detected in existing research and practice in the following matrix (Figure 10), using the three dimensions as its structure.

Figure 10. Matrix of Different Kinds of Accessibility



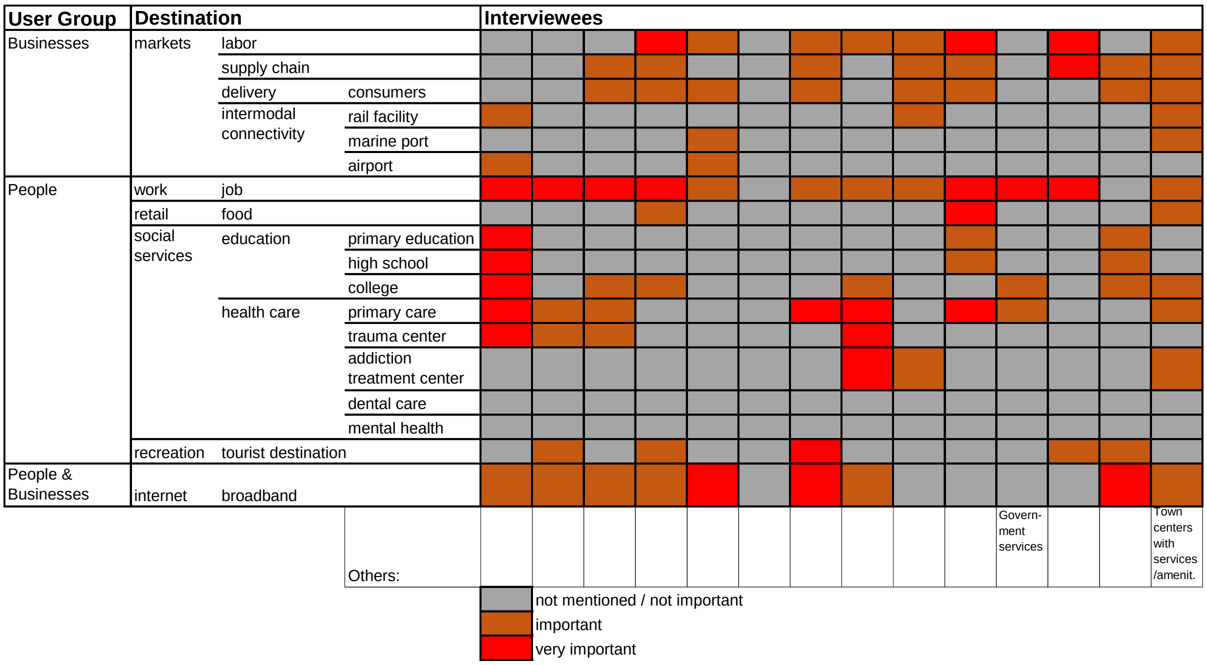
While these three dimensions define each kind of accessibility, there is an additional dimension that helps qualify them. For each kind of accessibility, one or multiple sub-groups may be of special interest. When we develop for example a metric to measure businesses' access to their consumers / customers, we may be especially interested in small businesses, because those are especially vulnerable to poor access. Or when we look into ways to measure access to primary health care, we may want to single out populations age 65 or older that are especially dependent on this kind of access.

Needs Assessed from Interviews

The research team conducted 14 interviews designed to gather perspectives from practitioners responsible for some aspect of transportation and mobility within Appalachia. The interviewees are listed in Appendix I and include representatives of USDOT, State DOTs, and Local Development Districts and MPOs.

As part of that process, we asked interviewees to share their views on which types of destinations are critically important for people and businesses in Appalachia. We then assessed their feedback quantitatively to organize each interviewee's responses according to whether they viewed a particular destination type as very important, important, or not important/not mentioned (Figure 11). While not a definitive scoring process, this evaluation provided insights into the priorities of a sample of practitioners who are likely to constitute the audience for measures developed as part of this research.

Figure 11 Matrix of Accessibility Priorities from Interviews



Most Relevant Kinds of Accessibility for Appalachia

Differentiation by Destination

As discussed above, there are a range of types of accessibility that may be of interest. To be most useful to Appalachian states, regions, and local governments this project seeks to focus on a set of accessibility measures that are narrow enough to provide targeted insight while still broad enough to address the access needs of Appalachian residents and businesses.

Figure 12 presents our suggested set of kinds of accessibility deemed most relevant for Appalachia, based on a combination of interview feedback and our collective team judgement. These measures reflect the findings of the earlier Chapters as well as a decision to focus on destinations that are particularly supportive of economic development. They are further described below.

Figure 12 Suggested Most Relevant Kinds of Accessibility for Appalachia

<table>
<tr><th></th><th>Access to …</th><th></th></tr>
<tr><td rowspan="6">Businesses</td><td>Labor</td><td></td></tr>
<tr><td>Supply chain</td><td></td></tr>
<tr><td>Delivery</td><td>Consumers</td></tr>
<tr><td rowspan="3">Intermodal connectivity</td><td>Rail facility</td></tr>
<tr><td>Port</td></tr>
<tr><td>Airport</td></tr>
<tr><td rowspan="7">People</td><td>Job</td><td></td></tr>
<tr><td>Education</td><td>College</td></tr>
<tr><td rowspan="3">Health care</td><td>Primary care</td></tr>
<tr><td>Trauma center</td></tr>
<tr><td>Addiction treatment center</td></tr>
<tr><td>Town centers</td><td></td></tr>
<tr><td>Tourist destination</td><td></td></tr>
<tr><td>Businesses and People</td><td>Broadband</td><td></td></tr>
</table>

Access for businesses:

- **Access to Labor.** This is a nearly universal consideration as access to workers is perhaps the single most significant factor in supporting businesses and affecting their location decisions.
- **Supply Chain Access.** This refers to business-to-business access, where businesses serve as suppliers and customers to one another, and in some cases as collaborators. This is often considered at the scale of same-day travel for either business or freight deliveries.
- **Delivery Access (Access to Consumers).** Whereas supply chain access focuses on connections between firms, this type of access focuses on access between businesses and their individual customers.
- **Intermodal Connectivity.** Given that the access provided by long-distance modes of travel such as air service or rail can be difficult to quantify directly, access to intermodal terminals can serve as a proxy form of access related to the ability of people and businesses to engage with the national and global economy.

Access for people:

- **Access to Jobs.** In the same way that access to labor is fundamental to business success, access to jobs is fundamental to the economic wellbeing of most individuals.
- **Access to Education.** Education is a key precondition to most, if not all, forms of economic development, particularly in an increasingly knowledge-oriented economy. Here we choose to focus on access to colleges rather than to primary and secondary school. While the latter are also fundamental to economic development, transportation access to K-12 education is typically assured through other programs outside the purview of ARC's core audience of DOTs and MPOs and is largely already sufficient.

- **Access to Healthcare.** Similarly, health is necessary to many forms of participation in economic development. Access to healthcare, therefore, is another form of basic access. Access to primary care supports ongoing health management while access to trauma centers addresses health care access in an emergency context. Trauma centers will also be often co-located with other specialized health services at hospitals. Addiction treatment centers were added to the list to reflect specific priorities from interviewees about the severity of the opioid addiction crisis in Appalachia and the need for better access to treatment.
- **Access to Town Center.** Based on feedback from interviewees, town centers were identified as proxies for a variety of destinations people desire or require access to including government services, retail, personal services, restaurants, and entertainment. These activities tend to concentrate in denser nodes of activity such as town centers.
- **Tourist Destinations.** Tourist attractions such as parks anchor a key sector of the economy within many parts of Appalachia, serving both residents and visitors from outside.

Access for businesses and people to:

- **Broadband.** In an increasingly networked world, availability, and quality of broadband internet service in rural Appalachia is a frequently cited constraint. Access to broadband can assist businesses and residents in overcoming the limitations imposed by distance or poor transportation access (e.g., by providing access to telemedicine or online education), and therefore merits consideration, if in a different manner than the other forms of accessibility.

Guided by this set of accessibility types, we further explore both the conceptual basis and data availability for additional dimensions of access including *differentiation by user group*, and *differentiation by network/mode.* An illustration of how different measurement approaches can fit together around specific access destination types is shown in Figure 13.

Figure 13 Illustration of differentiating user groups, destinations, potential metrics

User Group	Potential Differentiation of User Group by …	Access to …		Potential Differentiation of destination by…	Metric for Impedance (by mode)	Metric for importance of destination (options)
Businesses	Industry	Labor		Required education level	Travel Time (+potentially qualitative factors)	#Population
		Supply chain		-		#Jobs (Proxy)
		Delivery	Consumers	-		#Jobs (Proxy)
		Intermodal connectivity	Rail facility	-		Nearest facility
			Marine port			
			Airport			
People	Population work age Population by education Unemployed population	Job		Required skill level	Travel Time (+potentially qualitative factors)	#Jobs
	Population student age	Education	College	2-y, 3-y, 4-y college		Nearest college
	Population all groups	Health care	Primary care			Nearest physician #Physicians/#Population “Two-Step Floating Catchment Areas” by physician
			Trauma center	Level 1, 2, 3, 4		Nearest Trauma Center
			Addiction treatment center			Nearest addiction treatment center
	Population all groups	Town centers		Size or designation of town center		Nearest town center
	People outside of Appalachia	Tourist destination		National, state, regional designation		Nearest National, state, regional park/forest/monument
B&P	Population work age	Broadband			-	Binary (available in neighborhood Y/N)

Differentiation by User Group

Differentiation by user group refers to the possibility of analyzing access for a particular user group that is of policy interest, or that may have its own unique needs in terms of destination type. For example, an agricultural business may specifically be interested in access to bulk rail facilities. Alternately, Appalachian states, regions, and local governments may be interested in comparing access to colleges specifically for a "college aged" subset of the population. Differentiation by user groups requires data on subgroups at the same level of geographic resolution at which the access measures will be calculated. That data can then be used, for example, to develop weighted measures of access, where zones with more of the subpopulation are given more weight when aggregated across a region of analysis.

Differentiation by Network / Mode

Levels of accessibility can vary meaningfully by mode. Based on interview findings and the literature review, it is recommended that analysis of access in Appalachia at minimum consider access for people with and without cars (including people in households that may have fewer cars than drivers/adults). Pending data availability and priorities, additional detail could be developed on truck access for the subset of business measures that are oriented towards freight or for pedestrian/bicycle access for more localized destinations (e.g., town centers).

3.3 Data Availability

From all the data needed to assess accessibility in the intended comprehensive way, three different groups of data can be distinguished, each of which with its characteristic data sources. Data about population and employment serve different purposes within the concept of accessibility, both for user groups and for destinations of travel, but usually can be drawn from the same data sources. Specific additional data about destinations, as for example for education or health care, come from a variety of sources as broad as the destination categories themselves. Finally, network and travel time data are required to measure the ease to access any destinations.

The data source evaluation generally shows the capabilities and limitations of specific data sources to help inform the selection of metrics. It does, however, at this point not yet drill down to prove data availability including potential costs.

The entire list of considered potential data sources for all three groups of data can be found in Appendix II.

Population and Employment Data

Population and employment data can be used to measure accessibility in two different ways. They directly describe both user groups and some categories of destinations, e.g., the access to jobs. They may also serve as proxy variables for some of the destination categories. Because there is for example no specific information about consumers for delivered goods, population data can fill the gap, assuming that consumers are equally distributed among the population.

Figure 14 Categories of User Group and Destination Data Covered in this Chapter (light blue)

	Access to …	
Businesses	Labor	
	Supply chain	
	Delivery	Consumers
	Intermodal connectivity	Rail facility
		Port
		Airport
People	Job	
	Education	College
	Health care	Primary care
		Trauma center
		Addiction treatment center
	Town centers	
	Tourist destination	
B&P	Broadband	

Discussion of Dimensions and Requirements

The *geographic granularity* that is possible to achieve for accessibility metrics depends largely on the level of detail of population and employment data, as this data describes the two basic categories of users: businesses and people. Accessibility can considerably differ between various places within a county, which may include both urban and rural parts. Especially in mountainous areas of Appalachia, there is a requirement to be able to paint a more detailed picture of accessibility across the Region than to determine averages of vast and heterogenous counties.

→ Data sources on a sub-county level appear to be highly preferable.

The number of people with a given level of access could basically be measured by the number of people living in a given geographic area. However, a greater level of *detail of population group data* allows the design of accessibility metrics that are more targeted. If one accessibility metric is for example intended to measure access to colleges, then college-age populations are the most relevant as the user group for trips to those colleges. Besides age, other population characteristics like poverty status, educational attainment, or vehicle availability may play a role in the design of the accessibility metrics. More targeted accessibility metrics may prove to be more useful to decision makers.

→ Data sources for various population groups appear to add significant value beyond more aggregate data.

Similarly, there may be different requirements regarding the necessary level of *detail of employment data*. When we use the number of jobs in a geographic area as a proxy to measure its importance as a destination of business-to-business supply chain shipments, we may want to specify which industries may be the receiver of those shipments and use their employment counts specifically to measure their importance. Or when the number of jobs is used to weigh geographic areas against each other, e.g., when aggregating accessibility across geographic areas, there may be the need to differentiate between different industries. The access to ports, for example, is more important to manufacturing industries than to service industries.

→ Data sources that include industry detail also add value beyond the more common aggregate data.

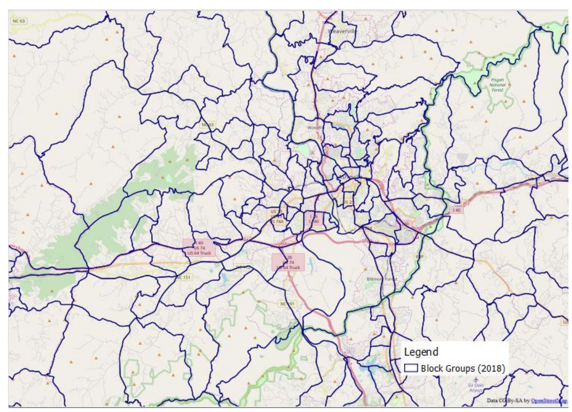
Potential Data Sources for Population

The potential data sources in the field of population are public. Census data from the American Community Survey (ACS) are in the foreground for any kind of population data. Their yearly updated estimations include the desired level of geographic and demographic detail.

The *geographic levels of detail* of the ACS data include state, county, sub-county, census tract, census block group, place, ZIP code. The suitable geographic level of detail should allow for a sufficiently granular measuring of accessibility and therefore depends on the size of those areas in rural Appalachia (compare Figure 15, Figure 16, and Figure 17). Additionally, the area level should cover the entire territory exhaustively, which is not the case for some of the area categories.

→ Data by census tract, census block group or ZIP code are in the foreground, depending on how granular they appear in rural Appalachia.

Figure 15 Census Block Groups in Western NC



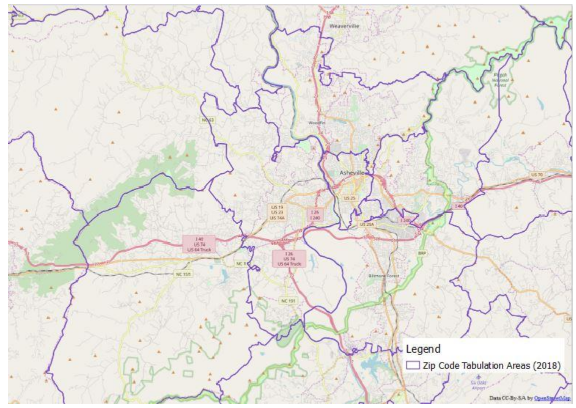


Figure 16 Census Tracts in Western NC

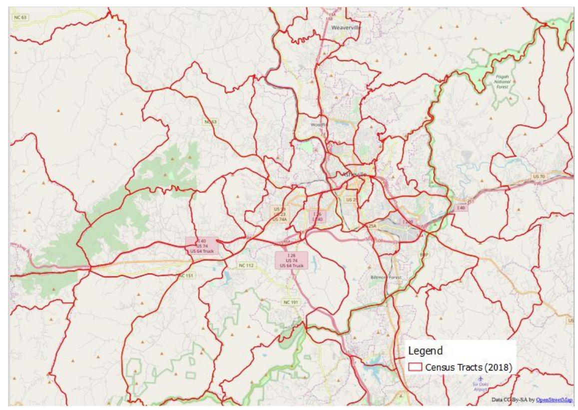


Figure 17 ZIP Code areas in Western NC

The *demographic details* provided by the ACS data include but are not limited to age, race, sex, poverty status, educational attainment, and vehicle availability[141]. They seem sufficient to target specific user groups for which accessibility metrics are desired.

→ Population data by age, vehicle accessibility and potentially educational attainment and poverty status are in the foreground, while other demographic characteristics seem less relevant for accessibility metrics in this study.

If necessary, ACS data can be complemented by the Public Use Microdata Sample (PUMS), which is a sample of actual survey responses rather than the modeled estimates from the ACS. However, at this point it does not appear probable that PUMS will be used. Because of sample sizes for geographic areas in Appalachia, it could only be used for highly aggregated areas and not for the desired granular portrayal of accessibility.

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141 ARC is working on an analysis to determine not only carless, but also “car-poor” households in Appalachia. The results may potentially be used for the implementation of the metrics identified in this study.

Potential Data Sources for Employment

Most of the data sources in this field are public. They all have their specific shortcomings, which may make it necessary to combine various data sources with each other. Complementing the public sources with proprietary data can enhance the level of detail that is possible.

The Quarterly Census of Employment and Wages (QCEW) provides a great level of industry detail for a current situation. However, it is available only at the county level, which would limit the capabilities of accessibility metrics based on this data source. County Business Patterns (CBP) are in contrast available on a ZIP code level, but the currently available most recent data is from 2016.

A private data provider, InfoUSA, delivers data by individual business (i.e., point data), which can be aggregated to industry-specific data for any geographic area. If both geographic and industry detail are seen as equally important, the purchase of this proprietary data may be advisable.

Conclusion

Based on the review of population and employment data availability, there are a few key implications for specification of an accessibility measurement approach for Appalachia:

- Mostly public data is broadly available with a great level of detail. This gives a lot of flexibility when designing the accessibility metrics, because they can be targeted to specific population groups or business industries.

- However, the use of both geographic and industry detail for employment may require the purchase of proprietary data

Additional Destination Data

Besides data about population and employment, a number of categories of destinations require specific location data.

Figure 18 Categories of Destination Data Covered in this Chapter (light blue)

	Access to …	
Businesses	Labor	
	Supply chain	
	Delivery	Consumers
	Intermodal connectivity	Rail facility
		Port
		Airport
People	Job	
	Education	College
	Health care	Primary care
		Trauma center
		Addiction treatment center
	Town centers	
	Tourist destination	
B&P	Broadband	

Education

There are various, mostly public, data sources for the locations of colleges. However, none of them seems to be designed for use in research, but rather for the needs of individual students. Further inquiries will therefore be necessary when implementing the metrics to assess the ease to obtain the entire dataset in a way that can be used in this study. The data sources allow the selection of specific types of colleges, usually defined by the program duration or by the attainable degrees.

Health Care

There is a large number of potential data sources for the location of health care providers. Many of the available maps and webtools about primary care providers, trauma centers and addiction treatment centers are sourced from public data but offered by non-profit organizations. Some of the data providers, however, appear to display data only about their members, which raises questions about the completeness of their data.

For the field of primary care, there are essentially two groups of data sources: those about individual physicians and others about health centers. It will have to be clarified whether the two categories as displayed in maps and lists are mutually exclusive or not. Physicians, who work at health centers, may be located there as well. More investigation will be necessary to find out in which ways the two kinds of primary care providers can be merged into one complete dataset of locations where primary care is provided.

Some of the data sources display density data instead of original location data of primary care providers. Metrics like population per physician within a given geographic area are helpful form of analysis but will presumably not be in the foreground for accessibility measures.

While this study will try to portray accessibility to destinations like health care providers in a consistent and exhaustive way, some of the health care data already include accessibility considerations in itself. The Rural Health Information Hub (RHIhub) for example applies specific criteria to health care providers which are displayed on their maps and data. Critical Access Hospitals (CAH) or Rural Health Clinics (RHC) are defined among other things by their rural location, their distance from other hospitals or their (limited) size. This kind of data does not appear suitable for this study since it does not allow for an unbiased consideration of all accessibility situations across the Region.

Town Centers

Town Centers are suggested to be used as a proxy destination for the availability of retail stores and personal services, which can usually be found in town centers. There is no good definition for town centers, though. The best, however imperfect, representation of town centers and thereby for destinations with retail and service offers appears to be the incorporated places from the Census categorization of geographies. They are cities, towns, boroughs, or villages with a population nucleus and usually a historic core.

An alternative approach, which can be assessed and compared to the census places, is the use of employment numbers by relevant industry, especially in retail stores and personal services (see Chapter 4.4).

Tourist Destinations

Designated parks and forests are in the case of Appalachia the most important category of tourist destinations. As for the national level, the data sources are obviously the National Parks directories. The state designated destinations may be just as important though and should be included. However, because the data sources for state parks are usually the states, this may be the only destination category for which there is not one single data source that covers the entire Region.

Conclusion

Based on this review, the location data for the selected additional destination categories is broadly available. Some categories require additional inquiries to determine how to make the most appropriate use of the data. Data availability will have to be explored with various private, mostly non-profit, data providers.

There is some uncertainty about the destination category of 'town centers.' The town centers themselves are a proxy destination for locations, which provide retail and service offers. Further analysis of the various potential data sources is shown in Chapter 4.4.

While for every other destination category the use of nation-wide data has been shown as possible, for tourist destinations this may not be the case. If, as suggested, not only National Parks, Forests, Monuments etc. are considered, there may be a necessity to use data sources from individual states to cover state parks, forests etc. as well.

Network / Travel Time Data

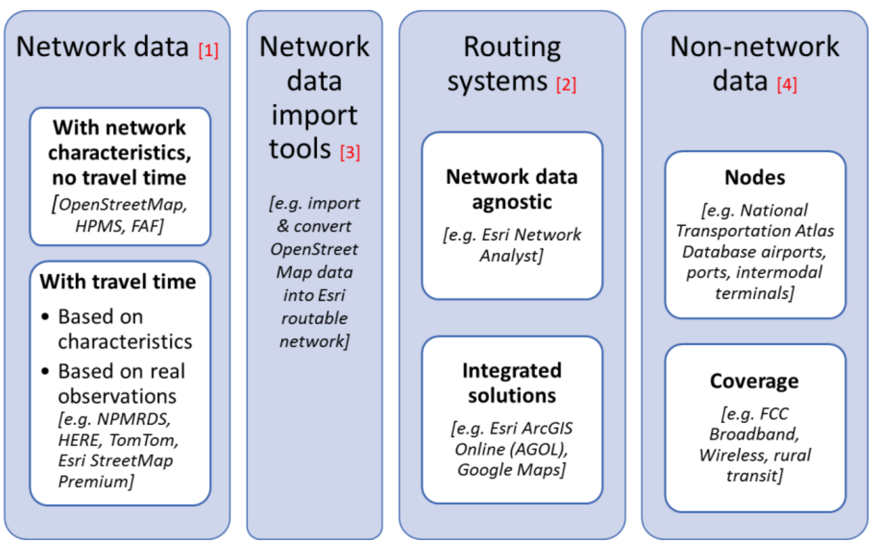
Discussion of Dimensions and Requirements

Network data is required to characterize the ability of the transportation system to connect users with their desired attractions or destinations. It addresses network availability and performance, which dictates whether trips are possible by a given mode and the "impedances" (i.e., travel distance, time, cost, reliability, etc.) that limit access between users and attractions/destinations. Travel time is the most commonly used impedance measure in accessibility analysis as it both conveys key outcomes of transportation network performance from a user's perspective and is easy to interpret. Therefore, the data availability review focuses on data sets and systems that can be used to estimate travel times while also recognizing that other factors (e.g., reliability, cost) may additionally be of interest.

Whereas regional and statewide travel models were once the dominant tool for estimating point-to-point travel times, recent years have seen a proliferation of increasingly accessible tools and data sets used to support multimodal routing, including through open source and/or publicly accessible systems (e.g., Google Maps). In this context of ever-increasing options, any review of data or tools is likely to be non-exhaustive. Therefore, it is more useful to present categories and key dimensions of network information, to inform discussion of accessibility calculation options.

Figure 19 illustrates four categories of network data. These are further described below.

Figure 19 Network Data Categories (Numbers in brackets correspond to order of descriptions below)



1. Network data: These data sets describe the spatial configuration and characteristics of the transportation network. Subcategories include:
    a. *Network data with network characteristics, but no travel times pre-calculated*. Example of this include OpenStreetMap[142], the Highway Performance Monitoring System (HPMS)[143], and the Freight Analysis Framework (FAF)[144]
    b. *Network data with travel time information associated*. Again, this can be subdivided into two classes:
        i. Where travel time is estimated based on network characteristics: This is usually produced as an interim step in an analysis and not published separately because it depends on specific configuration of estimation functions.
        ii. Based on observed travel times: This is typically derived from vehicle probes such as GPS systems or cell phones that can record the actual movement of vehicles. This form of data collection yields "big data" with many observations of speeds or travel times across times of the day, week, or year, thus providing resolution into issues such as congestion or bottlenecks. The level of data processing, cleaning, and aggregation varies in the available data sets. Examples include the National Performance Management Research Data Set (NPMRDS)[145], HERE[146], TomTom[147], and Esri StreetMap Premium.[148]
2. Routing systems: To make network data useful for accessibility calculations requires the analytical capabilities to find the fastest routes between points and calculate associated travel times. Routing systems have functionality that may include point-to-point routing, development of isochrones or service areas, and calculation of origin-destination impedance matrices. They also typically allow for some parameterizations of allowable connections (e.g., not allowing trucks over a certain height to use links with a height limit). This of course depends on availability of network data describing such restrictions. Routing systems are implemented in a wide range of technologies from more traditional GIS platforms (Esri ArcMap, QGIS) to web-based Application Programming Interfaces (APIs) and various others build to process geospatial data in database form. There are many ways to group these, but two are particularly useful when thinking about the procurement process for data:
    a. *Network data agnostic,* i.e., systems that can use any properly specified network data. An example of this would be Esri's Network Analyst.[149]

[142] https://www.openstreetmap.org.

[143] ESRI Geodatabase available from here: https://www.bts.gov/geography/geospatial-portal/NTAD-direct-download.

[144] http://osav-usdot.opendata.arcgis.com/datasets/560e1c2711f34aaf904fd8ab1f9333b9_0.

[145] https://npmrds.ritis.org/analytics/tutorials/.

[146] https://developer.here.com/.

[147] https://www.tomtommaps.com/mapdata/.

[148] http://enterprise.arcgis.com/en/streetmap-premium/latest/get-started/overview.htm.

[149] http://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/what-is-network-analyst-.htm.

b. *Integrated network data and routing systems*. In this case both the network data and the routing process are part of an integrated package. Examples include Esri ArcGIS Online (AGOL)[150] and Google Maps.[151]

3. Tools for importing network data into routing systems: There is actually considerable interoperability between routing tools and data sets. For example, there are many ways to process and import OpenStreetMap data into various routing systems. There are also hybrids that combine functionality of multiple systems such as Hqis[152] which is a QGIS plugin that allows for isochrone calculation and routing based on the HERE API[153] within QGIS.

4. Non-network transportation nodes and coverage data: In some cases, full network-based routing is not possible or practical. In these cases, data on the location of key multimodal transportation nodes or coverage of service may be used in constructing accessibility proxies. In this category the National Transportation Atlas Database (NTAD) includes location data for intermodal freight facilities, ports, and airports.[154] The Federal Communications Commission publishes data on fixed broadband[155] and mobile wireless coverage.[156]

Appendix II summarizes the reviewed network data based on the above categories, with additional information on level of available detail, most recent year of data and update frequency, information related to impedance estimates, modal coverage, and whether each source is public or private. Together these characterize a range of key dimensions that when matched to a vision for the end-use of the accessibility metrics should guide the selection of network data. These dimensions are further elaborated in Table 5 below.

Table 5 Network Data Decision Dimensions

Dimension	Notes/Considerations
Public versus proprietary	– Cost is the key issue here, although licensed uses may also be limited with proprietary sources – Proprietary sources may have usage-based pricing, with some basic usage being free
Ability to capture delay/congestion *(Estimated or observed travel times)*	– Important if benchmarking labor market access against congested urban areas – May also be important for capturing other sources of delay such as cars stuck behind trucks on roads with no shoulders or seasonal/weekend traffic near tourism destinations (depends on data resolution) – Less critical for destinations that tend to be accessed during off-peak hours – May be less critical for comparison among rural areas

150 https://route.arcgis.com/arcgis/.
151 https://cloud.google.com/maps-platform/.
152 https://github.com/riccardoklinger/Hqgis.
153 https://developer.here.com/.
154 https://www.bts.gov/geospatial/national-transportation-atlas-database.
155 https://broadbandmap.fcc.gov/.
156 https://www.fcc.gov/20th-mobile-wireless-report-web-appendices.

Dimension	Notes/Considerations
Level of network detail	– Some networks do not include local streets–may be serviceable for broader supply-chain analyses but not for more localized access analyses (including walking)
Modes	– Driving coverage is near universal – Walking and biking–frequently available – Special truck requirements in some cases – Transit a challenge (*see more detailed discussion below*)
Data quality and update frequency	– OpenStreetMap updated continually, but through crowdsourcing – Proprietary data is updated regularly and vetted – Federal data–some more limited release cycles

Transit Data Availability Challenges

Transit network data in Appalachia presents a challenge that merits special consideration. True transit accessibility measures rely on information on routes and schedules so that point-to-point travel times can be calculated. The most widely accepted sources of this information are General Transit Feed Specification (GTFS)[157] data. However, GTFS as currently implemented is designed to represent scheduled fixed-route service. Many rural transit providers only offer demand-response service or provide some combination of demand-response and fixed-route service.[158] While there are some efforts to develop GTFS extensions that could be used to encode information about demand-responsive services,[159] the vast majority of GTFS information applies to fixed-route service. In addition, many smaller transit agencies may lack the capacity to develop and share GTFS data. For this reason, published GTFS data coverage in rural areas is limited.

Figure 20 illustrates current data coverage of the National Transit Map, a project of the Bureau of Transportation Statistics to assemble GTFS data both fixed-guideway and fixed-route service.[160] Coverage of this data set may improve over time as more transit agencies are contacted to request data. CNT has also developed a proprietary dataset on transit service and access, including construction of GTFS data for agencies that did not have published feeds. However, the project is focused on metropolitan areas[161] with population over 100,00 and so coverage remains limited in rural areas.[162]

157 The General Transit Feed Specification defines a common format for public transportation schedules and associated geographic information.

158 NDSU. RURAL TRANSIT FACT BOOK | 2017. https://www.surtc.org/transitfactbook/downloads/2017-rural-transit-fact-book.pdf.

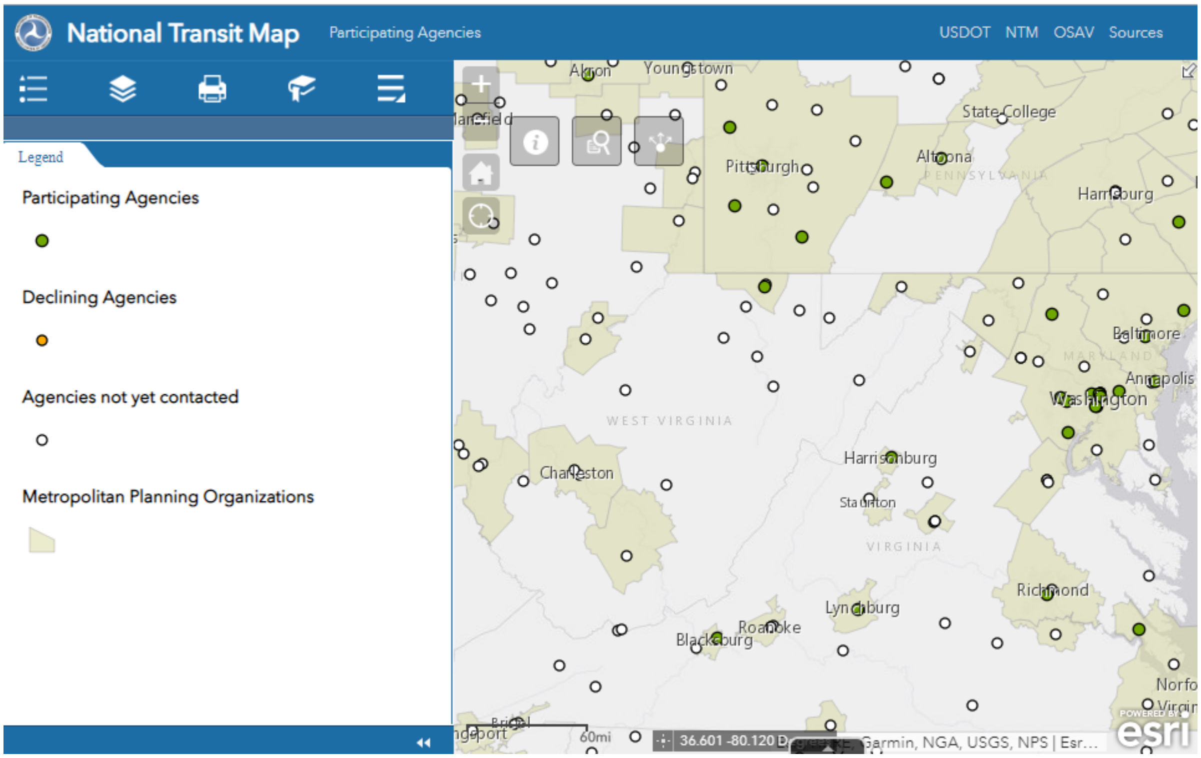
159 For example: https://github.com/MobilityData/gtfs-flex.

160 https://www.bts.gov/national-transit-map/about.

161 Defined as core-based statistical areas (CBSAs).

162 https://www.cnt.org/tools/alltransit.

Figure 20 Transit agencies providing GTFS data to the BTS's National Transit Map–illustration of coverage in parts of Appalachia



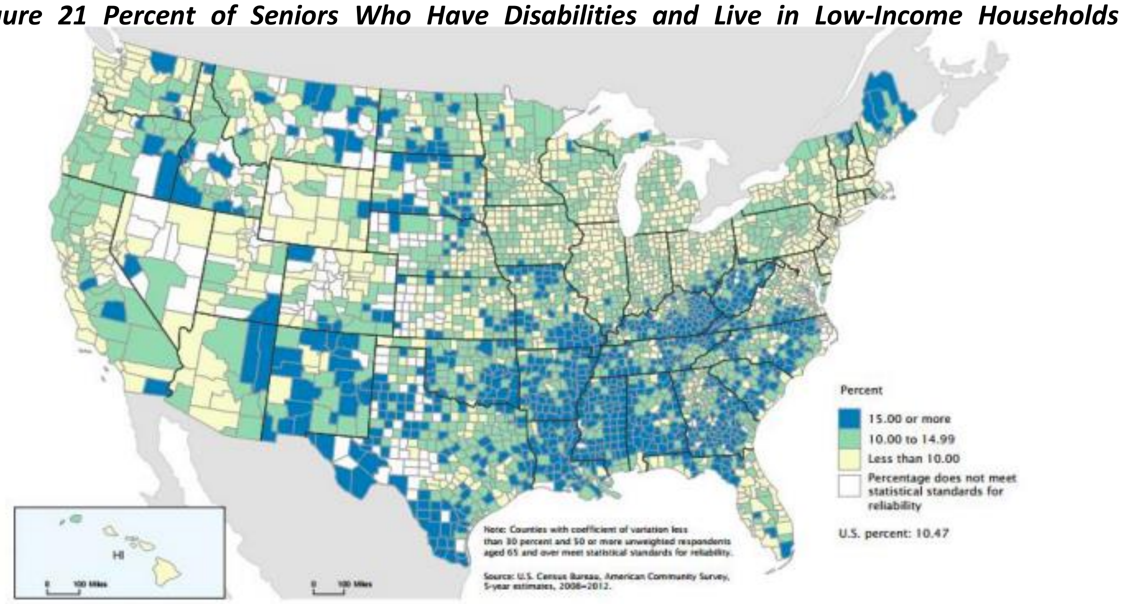
Source: National Transit Map Participating Agencies. (Screen shot as of February 2019)
https://maps.bts.dot.gov/arcgis/apps/webappviewer/index.html?id=8aa7d21846524c09a1fbf72d89e9b38d

There are a number of alternative approaches that can be taken to understand the prevalence of transit in rural areas that lack GTFS data coverage. These include:

1. Measuring transit usage outcomes. For example, data is available from the American Community Survey to profile transit mode share or from the FTA's National Transit Database (NTD) on annual public transit trips by agency. However, these types of indicators measure realized demand rather than access opportunities.

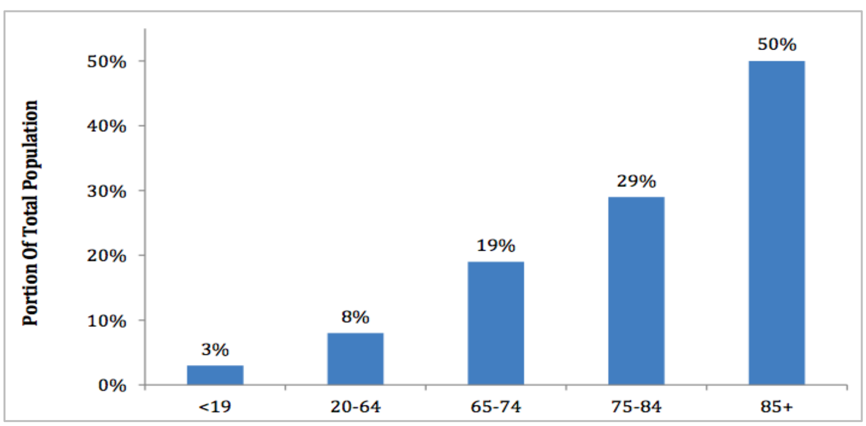
2. Measuring the prevalence of likely transit users/transit-dependent populations. These measures serve as a proxy or indicator of need, but do not provide any information on whether that need is met by the provision of transit services. Relevant populations include older residents, people with disabilities that would affect driving ability, adolescents, other adults in carless or car-poor households, and people without driver's licenses. Some of these populations are particularly prevalent in parts of Appalachia (Figure 21). These types of analyses might also involve researching correlations between available population measures and research on the subset of groups that are actually likely to be transit dependent. For example, Figure 22 looks at the relationship between age and difficulty traveling.

Figure 21 Percent of Seniors Who Have Disabilities and Live in Low-Income Households



Source: He and Larsen (2014) as cited in APTA. Public Transportation's Impact on Rural and Small Towns. https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Rural-Transit-2017.pdf.

Figure 22 Population by age group with a condition that makes travel difficult

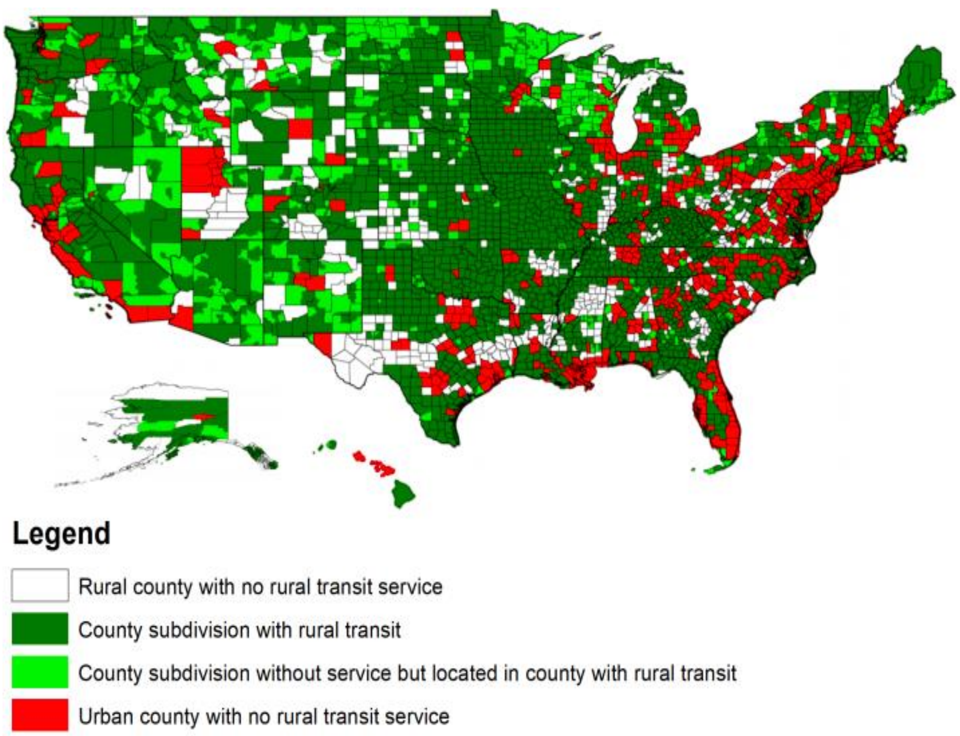


Source: Mattson (2012) as cited in APTA. Public Transportation's Impact on Rural and Small Towns. https://www.apta.com/resources/reportsandpublications/Documents/APTA-Rural-Transit-2017.pdf

3. Measuring transit service coverage/availability. In place of measuring travel times by transit, it may be more feasible to measure whether or not transit service is available to residents of certain areas. This in itself is a challenge given the range of types of providers that offer transit services. For example, Non-Emergency Medical Transportation (NEMT) is a Medicaid benefit typically coordinated outside the realm of what is thought of as "transit" but that nevertheless meets the needs of populations who have barriers to transportation access. Moreover, other health care providers/governments may offer this type of service to their customers beyond what is mandated by Medicaid, in recognition of the influence of access on outcomes and

healthcare costs.[163] Focusing on more classically defined transit, the best available national source of information on rural transit coverage is the North Dakota State University Rural Transit Factbook.[164] The Factbook profiles county-level coverage of transit providers supported by FTA Section 5311 funding (rural transit agencies[165]) and provides information on whether service covers all or part of a county, as shown in Figure 23. It also profiles tribal transit service coverage. Not included in these data are urban transit providers or providers not covered by the FTA's NTD data. More detailed coverage data may be able to be collected on a state-by-state basis.

Figure 23 Rural Transit Service Coverage (FTA Section 5311)



Source: NDSU. RURAL TRANSIT FACT BOOK (2017). https://www.surtc.org/transitfactbook/downloads/2017-rural-transit-fact-book.pdf

4. Substituting walk access measures where transit or transit data is unavailable. Typical transit routing and accessibility calculations already involve walking either for first/last-mile connections or, in the case of relatively short trips as a replacement for transit entirely if it is determined that walking is faster for a given origin and destination pair. Therefore, it is a natural extension to also consider walking as the replacement mode in areas where routable GTFS transit data is not available.

163 PatientEngagementHIT. What is Non-Emergency Medical Transportation, Patient Access? https://patientengagementhit.com/news/what-is-non-emergency-medical-transportation-patient-access.

164 NDSU. RURAL TRANSIT FACT BOOK (2017). https://www.surtc.org/transitfactbook/downloads/2017-rural-transit-fact-book.pdf.

165 FTA. Formula Grants for Rural Areas–5311. https://www.transit.dot.gov/rural-formula-grants-5311.

Conclusion

Based on the review of network data availability, there are a few key implications for specification of an accessibility measurement approach for Appalachia:

- Data is broadly available to calculate point-to-point travel times by car, walking, and biking. Some data is available describing special network restrictions for trucks.
- Transit data, however, is a challenge both because transit service in rural areas is not always provided in a scheduled fixed route manner that lends itself to point-to-point travel time calculations and because there is less GTFS data coverage of small transit agencies. This means that alternative approaches such as characterizing the coverage of transit service or considering walk time substitutes is necessary.
- A key decision going forward will be whether or not state, regional, and local governments wish to capture delay and congestion effects in their access measures based on observed travel times, as this will narrow down the network data options.

3.4 Ways of Measuring Accessibility

When specifying the functional form of accessibility metrics, there are two categories of quantification decisions to be made: (1) how to capture the importance of destinations or opportunities to which access is being measured, and (2) how the limitations imposed by travel impedances should be incorporated into the measure to mitigate the attractiveness of destinations. Options for each are discussed below.

Importance of Destinations

Methods for quantifying the importance of destinations relate to both (a) the format of data that characterizes destinations of interest and (b) to theoretical questions about what dictates the attractiveness or usefulness of different destinations from the perspective of the user. Options include:

- *Counting discrete opportunities* (e.g., number of schools, health care facilities). This is appropriate for point-based destination data, typically data about the location of individual establishments of a particular type.
- *Defining hierarchies of importance* granting a greater number of points to activities of a certain kind, quality, or scale (e.g., more points given to a Level I compared to Levels II-IV Trauma Centers). This is a natural extension of the first approach where there is additional data associated with destinations indicating that some are more attractive or useful than others. Theoretically, the same logic can be applied to magnitude data if it is stratified by type, with some types being more of interest than others.
- *Using indicators of magnitude* (e.g., population or employment). This option is typically employed where destination data is collected in terms of totals within zones as is the case with many forms of federal data that are aggregated to census defined boundaries.

In addition, there are ways to incorporate concepts of diminishing marginal returns into the measurement of destination importance. For example, when Virginia DOT measures local walk access to non-work destinations as part of its SMART SCALE prioritization, destinations are assigned limits to the number that are counted, reflecting a limit to the returns from additional accessible destinations. For example, when measuring access to grocery stores, the SMART SCALE approach only considers up to three occurrences.[166] The relevance of this type of approach varies by destination type. When considering access to trauma centers, there is a strong argument that only the first closest center matters whereas when people think of access to job opportunities, generally more is better because it increases the chances of finding a good match. Many destinations fall somewhere in between these poles. The challenge is to determine a sound theoretical basis for understanding the nature of diminishing returns and whether limits are appropriate.

Functional Form–Treatment of Impedance

Functional Form Options

Fundamentally, accessibility measures are designed to reflect the fact that destinations that take more time to access are, all else equal, less desirable, or useful than those located close by. Moreover, at some point travel times become unreasonable and a destination should be considered effectively inaccessible. The manner in which this underlying logic is incorporated into accessibility measures varies and falls into two primary categories:

- *Contour measures.* These include all activity reachable within a given travel time threshold.
- *Potential/gravity measures.* These sum all activities in an area of analysis, weighted by a function of impedance such that opportunities that take more time to access are granted less weight than those close to the point of origin.

Hybrid approaches of the above can also be implemented, i.e.:

- Summing of a series of weighted threshold measures, weighting the inner value more than the outer ones. For example, one might apply a weight of 1 to all activity within 15-minute thresholds, then a weight of 0.75 to all activity within a 16-30-minute time band, and so on.
- Implementing gravity measures within a given threshold. This can also be helpful in practically limiting the analytical search space.

There are also approaches where measures only address access to the *nearest destination*. This implies either that access to additional destinations after the first one is not meaningfully better and/or that the purpose of the analysis is address a basic form of minimal access or sufficiency. Intermodal connectivity is often treated this way (i.e., access to the closest airport).

166 SMART SCALE Technical Guide.

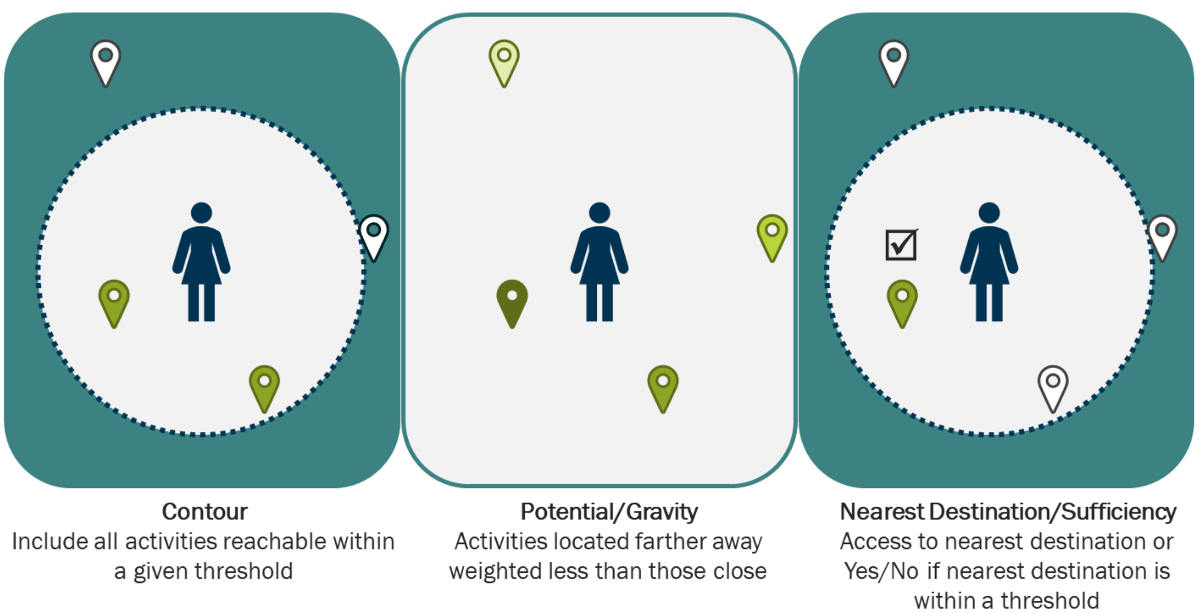
In this situation, there are a few distinct measurement options:

- Measuring travel time to closest opportunity.
- Constructing a measure of the general form where
  Access = (Measure of the importance of the destination) / (Travel time). For example, one might measure volume at the port as a proxy for its relative importance.
- Binary sufficiency measures. i.e., a yes or no on whether at least one destination is accessible within a defined threshold.

Figure 24 illustrates how these different functional forms of accessibility measures would treat the same spatial configuration of users and destinations. Note that these diagrams are presented in terms of straight-line distance (meaning thresholds appear as circles) but actual measures would use travel time and therefore not have perfectly circular boundaries.

In the case of the contour measure, only the two destinations within the threshold matter. They also "count" at the exact same level of importance even though one is considerably close. The diagram also highlights the somewhat arbitrary nature of threshold selection. The third closest destination lies just outside the boundary but is treated as providing no value, compared to the one just inside the threshold. On the other hand, the potential/gravity type measure instead recognizes all the destinations along a continuum of importance based on how far away they are. Finally, the nearest destination/sufficiency type measures only recognize the one closest destination, with all others treated as irrelevant.

Figure 24 Illustration of Different Functional Forms of Accessibility Measures



Source: EDR Group (now EBP)

Table 6 presents some of the pros and cons of contour versus potential/gravity measures. They each have strengths and weaknesses that appeal to different types of audiences. In general, it may be advisable to select the functional form of a metric for each kind of accessibility individually.

Table 6 Pros and Cons of Contour v. Potential/Gravity Measures[167]

	PROS	CONS
CONTOUR	• Easy to interpret, communicate, calculate • **May be more attractive to general users/high-level decision-makers**	• Thresholds are inherently arbitrary • No differentiation of opportunities within isochrone • Can be very sensitive to travel time changes which can make it harder to use in evaluating transportation/land use changes.
POTENTIAL/ GRAVITY	• Addresses many of the theoretical issues of contour measures • **May be more attractive to researchers interested in detailed comparisons or assessing the socioeconomic implications of accessibility differences**	• Hard to interpret/communicate • Requires selection of a specific decay function

Selecting Thresholds or Distance Decay Functions

Thresholds or parameters of spatial decay functions are typically chosen to reflect travel behavior. In practice, this can mean either (a) selecting "rule of thumb" thresholds (e.g., 60 minutes), or (b) selecting thresholds or parameterizing decay functions through analysis of empirical data on spatial travel behavior. The latter approach relies on data describing the distribution of trip durations, stratified by variables of interest—namely trip purpose, mode, and location/area type. The National Household Travel Survey (2017) offers a recently updated national data set of this type.

For potential/gravity measures, the most common functional form is a negative exponential function of the form:

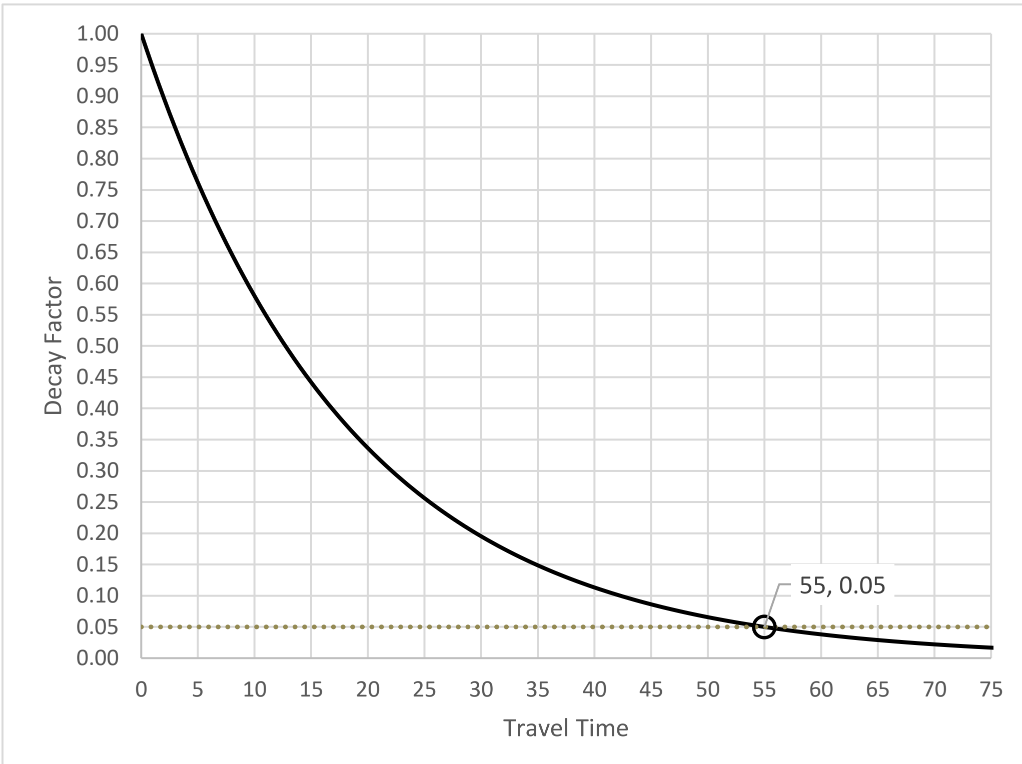
$$A_i = \sum_{j=1}^{n} D_j e^{-\beta t_{ij}}$$

Where A_i is the accessibility of zone i to all destinations in other zones (j) and t_{ij} is the travel time between zone i and zone j. D_j is a measure of the importance of destinations in zone j. Here β determines the shape of the decay function that mediates the opportunity offered by the destinations. Where travel time is zero, $e^{-\beta t_{ij}} = 1$, meaning the full measure of the importance of the destination is counted. For any travel time greater than 1, that factor becomes a fraction reducing the weight given to the destination opportunity. One approach to choosing the parameter β is to find the 95th percentile of travel time for a mode/trip purpose/region type of interest and then set β such

[167] Derived in part from: Geurs and Wee. Accessibility measures: a literature review. Available at: https://dspace.library.uu.nl/bitstream/handle/1874/9299/c2.pdf.

that if $t_{ij}=t_{95}$, then $e^{-\beta t_{ij}} = 0.05$. For the sake of illustration, if travel data shows that 95% of school trips are less than 55 minutes in duration. this would mean a β of approximately 0.054 calculated as described previously and would yield a decay function of the shape shown in Figure 25. Other functional forms could be specified to account for possible threshold effects in the sensitivity to travel time. For example, while travelers might not differentiate considerably between 5 and 10 minutes of travel time, it is possible that once a certain threshold is reached, the perception of the barrier posed by travel time increases significantly.

Figure 25 Illustration of negative exponential function



3.5 Recommendation for Set of Accessibility Metrics

This Chapter summarizes our suggestion for the set of core metrics, any complementing (portraying) metrics and the most adequate methodologies to measure the metrics.

Metrics Key to Economic Development

Based on their development in the previous Chapters of this report, we suggest the metrics shown in Table 7 through Table 9 to be the set of core metrics that corresponds most directly to economic development needs in Appalachia. Each of the metrics is described briefly after the table. For some of the destinations, additional complementary metrics are mentioned that help portray accessibility to this kind of destination more comprehensively.

User Group: Businesses

Out of all the accessibility needs businesses or specific industries have, the following set of core metrics is selected as being of more direct relevance to economic development outcomes in Appalachia.

Table 7 Suggested Core Metrics for Businesses (Numbers refer to NAICS Industry codes)

Business Specification	Access to …		Destination specification
All	**B1. Labor**		Associate's 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

B1. Businesses' access to labor markets is similarly important to all industries, which is why we suggest not to distinguish between different industries. Businesses will typically prefer potential workers with Associate's degrees or higher over other workers.

Suggested Complementary Metric: **The core metric can be complemented by an additional metric not specifying the required education of potential workers.**

B2. Regarding businesses' **supply chain** access, we suggest two core metrics with distinct associated modes:

- With freight in mind, manufacturing industries are at the core of this kind of accessibility.
- In contrast, all industries rely critically on access to business-to-business contacts, be it as partners, customers, or service provider.

Employment data will serve as a proxy variable for the distribution of supply chain connections across the Region, serving as a representation of business activity.

B3. Trade and warehousing industries (including retail) are most reliant on the **delivery** to consumers. The consumers are represented by the distribution of population.

Suggested Complementary Metric: A complimentary metric considers all industries as depending to some extent on access to their consumer markets.

B4. We suggest defining core metrics for each of the three types of **intermodal facilities**. Freight-dependent industries like manufacturing and trade and warehousing are in the foreground for a core metric measuring the access to (a) rail freight facilities and (b) coastal ports. Airports (c), in contrast, meet an access need shared by all industries, some of them for passenger travel of their employees, and others for air cargo.

Suggested Complementary Metrics: A more specific metric, measuring access to (a) intermodal container terminals, is especially important to manufacturing and trade and warehousing industries. In contrast, focusing on (b) inland waterway ports lead to agriculture and mining as potentially most interested shippers of bulk goods through inland ports. A differentiation between different kinds of (c) airports leads to manufacturing and trade and warehousing as industries most interested in access to top airports for air cargo, while all industries are likely to value good access to a commercial service airport.

User Group: Population

People have different accessibility needs, which also vary by population group. The following set of core metrics is selected to best encompass the economic development purpose of accessibility.

Table 8 Suggested Core Metrics for Population

Population Specification	Access to …		Destination specification
Age 18-65	**P1. Job**		Employment
Age 18-24	**P2. Education**	**College**	All
All	**P3. Health care**	**a) Primary care**	General Practice
All		**b) Trauma center**	All
All		**c) Addiction treatment center**	All Substance Abuse
All	**P4. Town centers**		All
All	**P5. Tourist destination**		National and State Designated

P1. Access to jobs is most important to working age populations, age 18-65. The availability of jobs is represented by the distribution of existing employment.

Suggested Complementary Metrics: It is critically important for unemployed people to have access to jobs. Additionally, population affected by poverty are of interest regarding their access to jobs.

P2. Access to **colleges** is most important to college-age population groups. All colleges are considered, regardless of the type of degree (2-year, 4-year).

Suggested Complementary Metrics: Since colleges can also be the location for job training for professionals, the working age population (age 18-65) is additionally considered for access to colleges. Again, poor population groups are included in an additional complementary metric.

P3. Three distinct kinds of destinations are considered for access to **health care**. No population groups are distinguished for the core metrics. (a) Among the primary care providers, access to general practitioners is selected as being most important to the broad population. (b) Similarly, no population group is more important than another regarding access to trauma centers. Trauma centers of all levels are considered for emergencies. (3) All population groups may be affected by addiction. Their access to Addiction Treatment Centers is similarly important.

Suggested Complementary Metrics: (a) For children and adolescents (age 0-17), access to pediatrics may be equally important as access to general practitioners to adults. (b) Level 1 and 2 trauma centers have enhanced opportunities to help patients, who are critically ill or injured. Access to those is treated as a complementary metric. For all kinds of destinations (a-c), poor population groups' accessibility to health care institutions is again of special interest.

P4. All population groups drive demand for retail or personal services and are therefore equally included in the core metric of **town center** accessibility.

Suggested Complementary Metrics: Poverty-affected population groups are of special interest.

P5. All population groups may be equally interested in access to tourist destinations. National and state designated parks, monuments and forests are considered as **tourist destinations**.

Suggested Complementary Metrics: Again, poor population groups are specifically analyzed regarding their accessibility.

Broadband Internet

Broadband internet can assist in bridging gaps where physical accessibility is insufficient for any or all groups of the population. Table 9 shows what is regarded a sufficient technology to serve this purpose.

Table 9 Suggested Core Metrics for Technology

Access to …	Sufficient Speed/Technology
T1. Mobile Broadband (i.e., Cell Phones)	LTE
T2. Fixed Broadband (i.e., at home)	≥ 25/3 Mbps download/upload

T1. LTE is regarded the necessary standard for good mobile broadband internet access.

T2. The Federal Communications Commission defines a download and upload speed of ≥ 25/3 Mbps as the baseline speed benchmark for **fixed broadband** internet access.

Methodologies to Build the Metrics

Concluding from the methodological considerations and from their discussion with ARC, we suggest using the following outline of our methodologies for building the metrics:

- *Geographic Unit:* For an adequate geographic granularity of measuring accessibility, we will use the smallest census unit with generally available associated data, the block group.
- *Starting point:* One or more points within the geographic unit will serve as starting point(s) for the measurement of the accessibility metric. This will be further explored in Chapter 4.
- *Function:* Generally, for rural Appalachia distance decay functions are seen as the preferable form of the accessibility function for most metrics. A "nearest destination" approach may be more appropriate, though, for some destinations (trauma centers, coastal and inland ports, intermodal rail facilities, airports). This will be further explored in Chapter 4.
- *Importance of destination:* While for some metrics the importance of the destination is actually measured by counts of people or jobs, for other metrics individual potential destinations of its kind are not weighted by importance in any way within one metric (e.g., trauma centers of a certain level are equals).

Ways to Use the Metrics

Once implemented as envisioned, the metrics may be useful to various audiences in different ways. Planning and programming agencies can make use of an accessibility metrics in several phases along the planning process and other actors may have their own purposes for using the metrics.

- *Deficiency assessment:* In early stages of the planning and programming process, the identification of areas with poor accessibility may help understand the needs in terms of transportation network and performance improvements to address deficiencies. Maps as well as scores may serve as means of conveying differing qualities.
- *Comparison of Appalachian Region with areas outside of the Region:* State, regional, and local entities may want to demonstrate the quality or lack thereof of access within the Region as compared to neighboring parts of the 13 states. Maps as well as scores can be useful to identify discrepancies and to show them to targeted audiences.
- *Integration of accessibility criteria into project evaluation and prioritization:* Agencies may choose to directly integrate one or more metrics as criteria in their planning or programming process. For example, projects might be given additional points within a prioritization process if they are located in areas in the 10^{th} percentile (i.e., the bottom 10%) of accessibility scores and if the project is expected to improve access.
- *Addressing deficiencies and monitoring of outcomes:* Responding to information about access conditions, agencies may try to address specific accessibility deficiencies through corresponding transportation improvements. If the access metrics are updated at intervals with new data, they could then also be used to track changes over time and evaluate the effects of transportation improvements after the fact.
- *Planning support to other actors:* Other entities besides government agencies may be interested in using the identified access metrics if made available through a tool or similar accessible platform. Health care providers or colleges may be interested in assessing their potential patients’ or students’ physical access to their locations. Business organizations may want to use a tool to learn about their constituents’ options to reach their markets. Or private transportation service providers may want to know where their catchment area overlaps with areas of poor access by various means of transportation.

4 Exploratory Analyses and Example Maps

4.1 Introduction

This Chapter presents the findings of a set of exploratory analyses and example mapping exercises conducted. These proofs of concepts support conclusions and recommendations for the implementation vision presented in Chapter 5. The demonstrations presented in this Chapter fall into three categories:

- Analyses: Suggested data sources and methodologies are analyzed with regard to their ability to capture specific aspects of accessibility in Appalachia.
- Maps: Ways to build specific metrics are presented in maps to demonstrate their respective legibility for the project's anticipated audiences.
- Concepts: Further development of accessibility measurement/representation concepts.

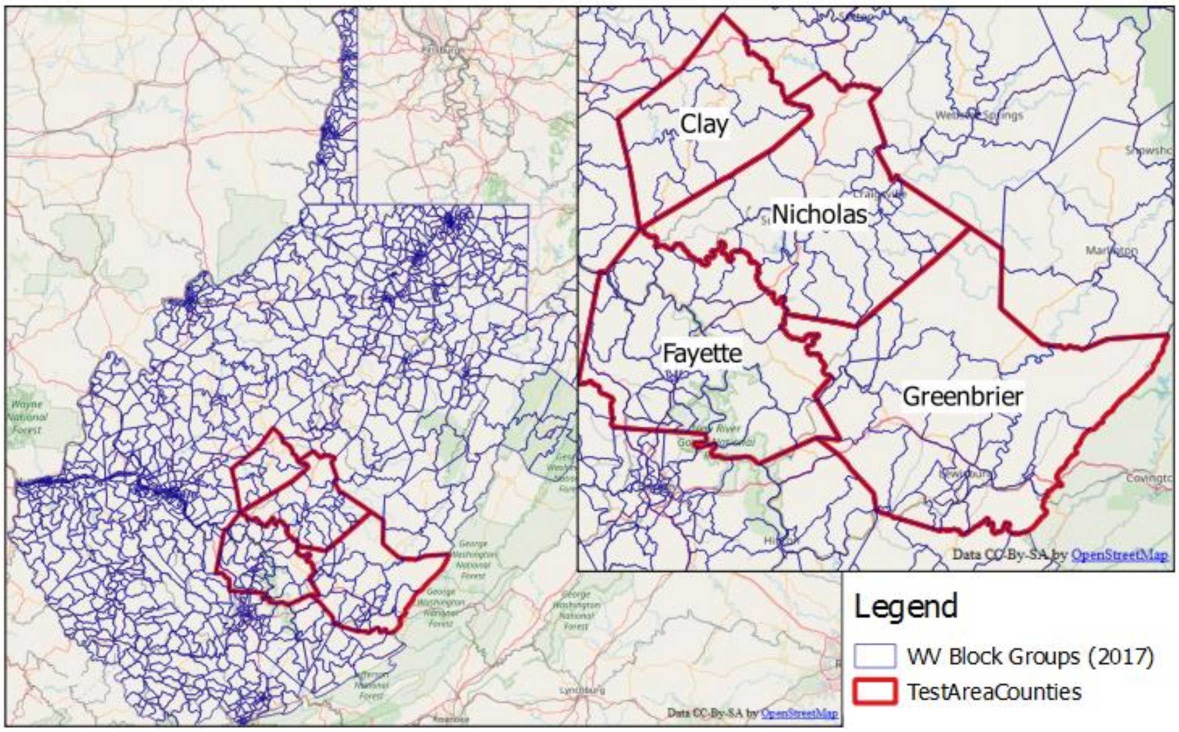
4.2 Test Area

For the purpose of test calculations and mapping, we have selected a geographic area with typical characteristics for Appalachia for use across the demonstrations. The test area is comprised of:

- Clay county, WV–part of Charleston WV metro area
- Fayette county, WV–part of Oak Hill WV micro area
- Nicholas county, WV
- Greenbrier county, WV

This area was selected to show a range of urban and non-urban areas and is shown in Figure 26.

Figure 26 Test Area in West Virginia



Source: EDR Group (now EBP) mapping using data from OpenStreetMap and IPUMS NHGIS.[168]

4.3 Identification of Point(s) Best Representing a Geographic Unit

Purpose

Accessibility metrics will be calculated for entire geographic units. This requires identifying the point(s) that best represent(s) the unit, in this case a Census block groups. Additionally, because our accessibility framework differentiates between accessibility needs for businesses and people, the representative point may differ depending on the perspective of the measure.

[168] www.nhgis.org

Methodology

Using the test area, we explore various ways to determine the origin or destination point(s) of travel time measurement:

- Geographic centroid, or
- Population- or employment-weighted centroid.

Depending on the metric, either the population or the employment-based centroid within a geographic unit may be the best representation of where trips start or end. If, for example, the metric measures access to work, the origin may be at the population centroid, and travel time is measured to the employment-weighted centroid at the destination.

Because our unit of measurement is the block group, employment and population data at the block level is used to calculate the weighted centroids. Block level total employment data is drawn from Workplace Area Characteristics of the LEHD Origin-Destination Employment Statistics (LODES).[169] 2015 is the most recent year for which data at this geographic level of detail is available. This data was extracted in easy-to-process point data (where a point represents a block) from the LEHD OnTheMap tool.[170] Block level total population data is most recently available from the 2010 decennial census.[171]

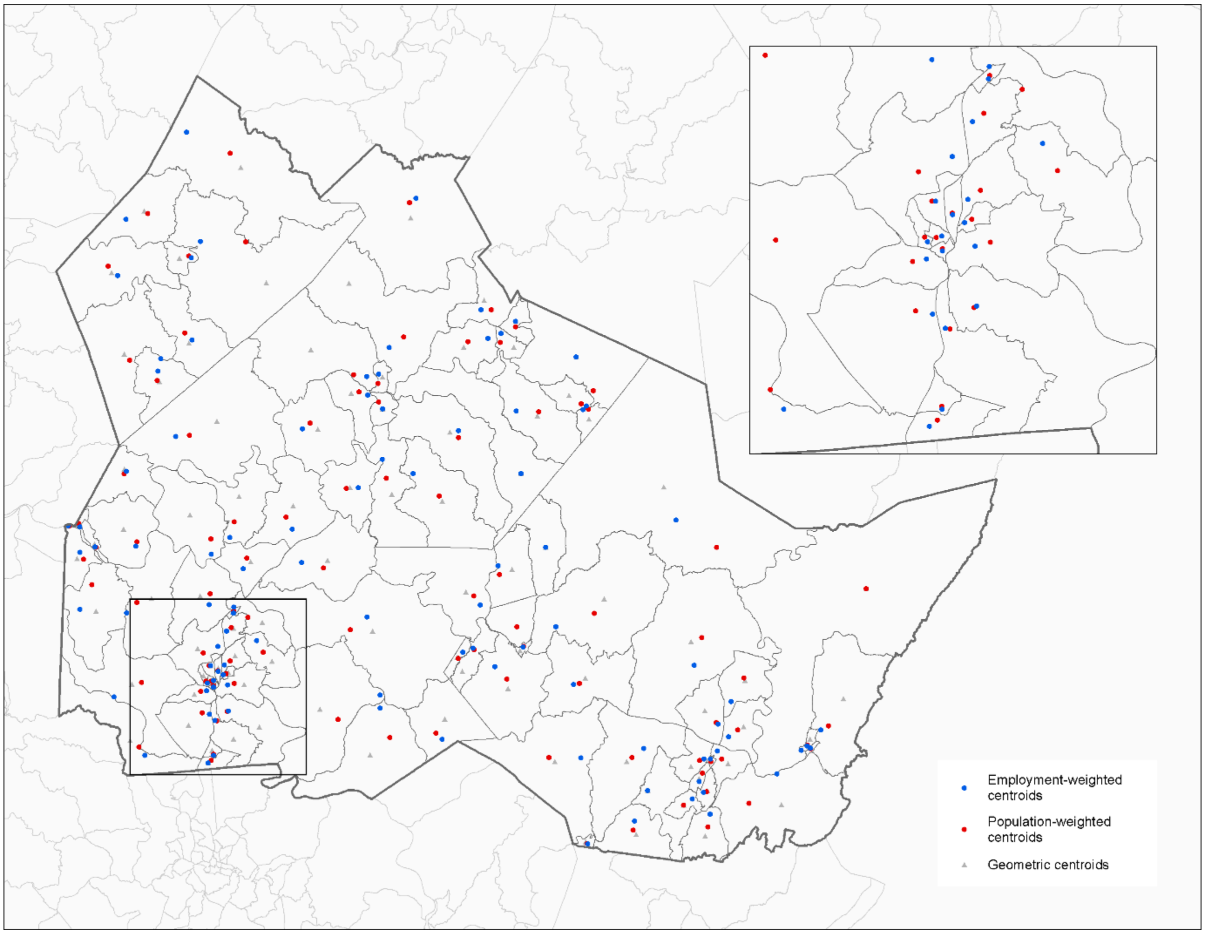
Results and Recommendations

Figure 27 shows the results of the analysis, illustrating geometric centroids, population-weighted centroids, and employment-weighted centroids within the test area. Geometric centroids are calculated so as to always fall inside the boundaries of a block group even when block groups have concavities. Population- and employment-weighted centroids can lie outside their own block group.

For this reason, we recommend the representative points used in accessibility calculations be either the population- or employment-weighted centroids (depending on the measure's perspective), except where these are outside the block group, in which case the respective point would be replaced by the geometric centroid. This ensures that points are as close as possible to relevant centers of activity, while enforcing that the origin or destination point for any calculation is in fact inside the respective block group.

169 https://lehd.ces.census.gov/data/
170 https://onthemap.ces.census.gov
171 Downloaded from: IPUMS NHGIS, University of Minnesota, www.nhgis.org

Figure 27 Centroid Options in the Test Area



Source: EBP analysis using data from LEHD and from the Census, extracted using IPUMS NHGIS.

4.4 Data Sources for Retail and Personal Services

Purpose

The accessibility metric P4, Access to Town Centers, seeks to capture people's access to retail stores and personal services, in rural areas traditionally located in town centers. The point that best represents significant destinations for these trip purposes needs to be defined separately, as retail and personal service uses are not always distributed in the same ways as population or jobs. The purpose of this Chapter is to identify the best data source for this definition.

Methodology

We reviewed three public and one proprietary data source that provide retail and personal services information for rural geographies. Table 10 lists the data sources reviewed and key characteristics for each.

Table 10 Characteristics of Considered Data Sources for Retail and Personal Services

	Infogroup	LEHD	OnTheMap	Census Places
Domain	Proprietary	Public	Public	Public
File type	Point	Polygon	Point	Point
Geographic unit	Establishment	Block	Block	Location
Industry detail	2 and 4-digit NAICS	2-digit NAICS	2-digit NAICS	Population, employment etc.
Latest vintage	2019	2015	2015	2017
Cost	$0.08 per record	Free	Free	Free

Infogroup is a private company that provides current, geocoded business establishment data up to a 4-digit NAICS level of industry detail. Standard pricing for Infogroup data is $0.08 per establishment record, with the cost increasing for each record attribute added. At least four attributes are necessary to map Infogroup data. These include address, city, state, and number of employees. This means that mapping all retail and personal services establishments in Appalachian states could become prohibitively expensive. Infogroup does offer discounted pricing for clients needing access to a significant number of records. Using this data would potentially involve a process to determine a destination point best representing all records in a geographic unit.

Longitudinal Employer-Household Dynamics (LEHD) is a United States Census product that provides population and 2-digit NAICS employment data down to a Census block level. **OnTheMap** is also a Census product that represents LEHD data using points instead of polygons. Both data sources are free and 2015 is the latest year for which data is available.

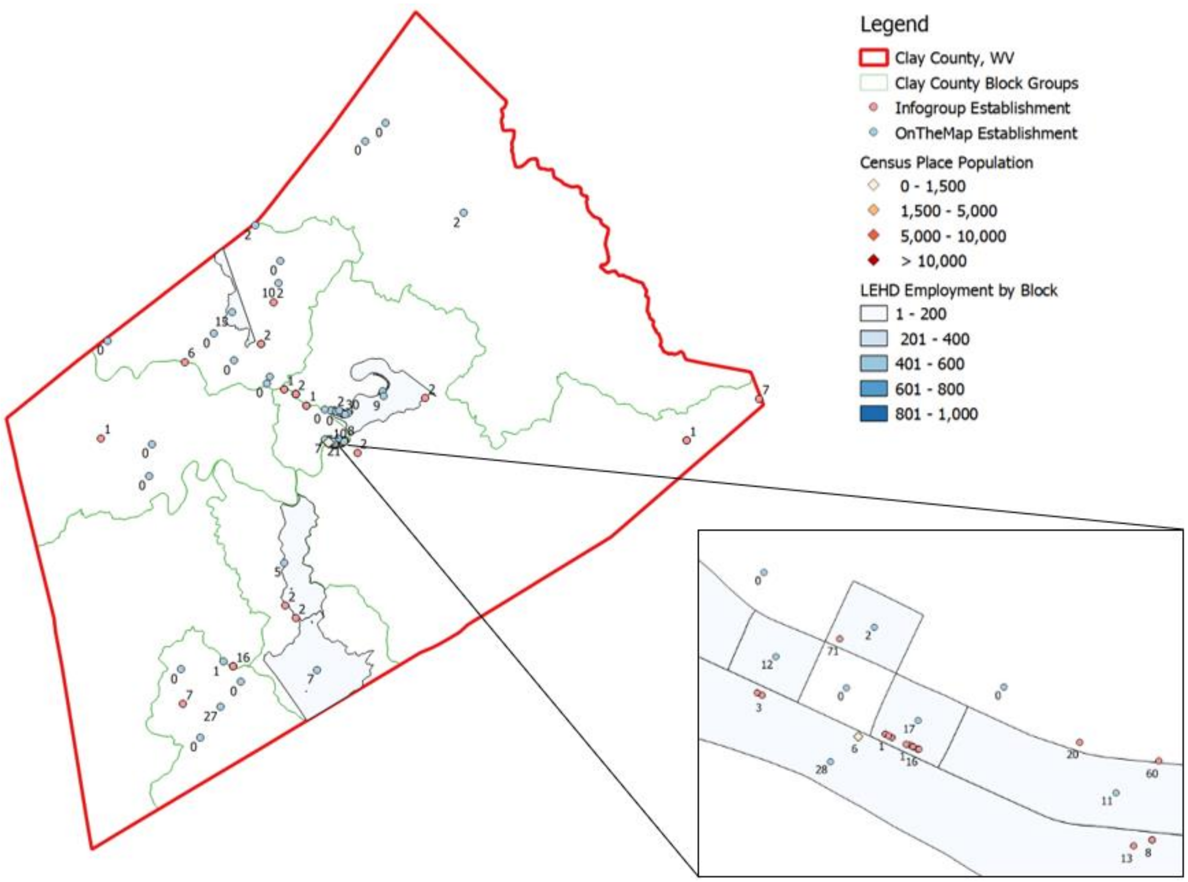
Census Places are designated by the Census. They represent concentrations of population and are either legally incorporated entities such as cities or are an unincorporated statistical equivalent designated by the Census to capture a population concentration. The IPUMS National Historical Geographic Information System (NHGIS) has developed a corresponding product that contains points "located within the historical, functional center of [a] place (e.g.,, the central business district of a city)."[172] While this place data is not directly associated with employment, it can provide an indication of where retail and personal services employment is concentrated, if they are co-located with historical cores of places.

[172] https://www.nhgis.org/documentation/gis-data/place-points

Results and Recommendations

The map in Figure 28 shows Clay County, West Virginia, a rural Appalachian county from our defined Test Area. We chose to illustrate the sufficiency of retail and personal services employment data using this county. Notice that there is one OnTheMap point for each Census block whereas Infogroup points represent the actual location of a single establishment. Also notice how the LEHD polygons do not provide full spatial coverage across the county, as they show only data where there are jobs in retail or personal services reported.

Figure 28 Map of Retail and Personal Service Representations for Clay County, WV



We recommend using OnTheMap data for the purpose of analyzing access to retail and personal services establishments. While OnTheMap data is not as current or geographically precise as Infogroup data, it shows employment levels and is free-of-cost. The employment numbers are in the same order of magnitude. Census place data will likely be unhelpful in rural areas like Clay County because in this case it shows only the center of the county even though there are areas of employment outside the center.

4.5 Travel Time Data Options

Purpose

As described in previous Chapters of this report, different kinds of network data sources exist, from which travel time information for cars and trucks can be calculated. In particular, this Chapter explores two sources with different capabilities:

1. **OpenStreetMap data routed using OpenRouteService**[173]: In this approach, travel time estimates are based on network attributes. The data is open-source and therefore free.
2. **Esri's ArcGIS online network data and geoprocessing capabilities**: Esri utilizes data collected from vehicle probes about actual observed travel times and is proprietary with associated licensing costs.

The purpose of this demonstration is to address the following questions:

1. How does the open source network data set available from OpenStreetMap compare to proprietary network data? I.e., does OpenStreetMap data appear sufficiently accurate?
2. How do travel time estimates at specific times of day compare to average reported travel times, with no specific departure time? That is, does congestion appear to make a meaningful enough difference that we should consider calculating different travel times for different measures at different times of day?
3. How do travel time estimates for cars differ from estimates made with truck specific routing assumptions? Are differences meaningful enough to consider separate car and truck travel time calculations?

Methodology

We conducted a series of origin-destination travel time calculations between four selected block groups within the test area. The block groups were chosen to show a diversity of contexts and degree of connectivity to the road network, as shown in Figure 29:

1. A block group located just outside Summersville, WV
2. A rural block group located in the northernmost part of Greenbrier County, WV
3. A block group covering the city of Lewisburg, WV
4. A block covering portions Babcock State Park and the New River Gorge National River, a National Park

Travel times were calculated between all combinations of these four block groups, using the network data and routing described below.

[173] https://openrouteservice.org/

From Esri's ArcGIS Online network data using the Origin Destination Cost Matrix tool:[174]

- Car travel times with no time of day specified
- Car travel times with a time of 9 am specified
- Truck travel times with no time of day specified
- Truck travel times with a time of 9 am specified

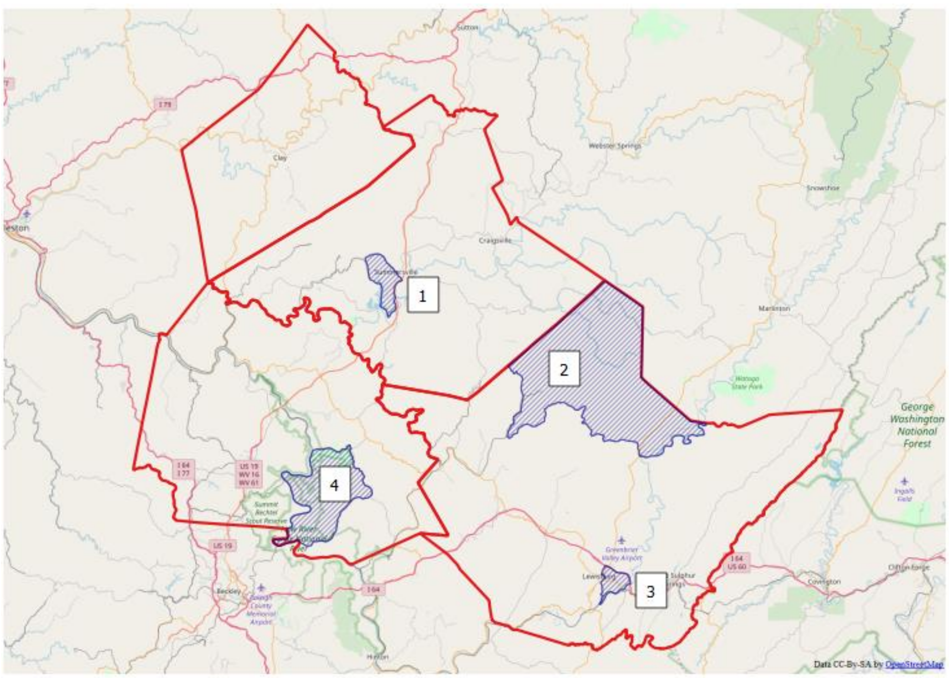
According to Esri documentation, truck times avoid routes that are truck restricted and will prefer roads that are designated as truck routes or roads that are preferred by trucks.

From OpenStreetMap network data routed using OpenRouteService[175]*:*

- Car travel times (no time of day or traffic information available)
- Truck ("heavy vehicle") travel times ((no time of day or traffic information available)

In addition to the above, the same set of origin and destination pairs was also analyzed using Google Maps[176], as an external source for general validation.

Figure 29 Selected Block Groups for Travel Time Analysis



Source: EDR Group (now EBP) mapping using data from OpenStreetMap and IPUMS NHGIS.

[174] https://pro.arcgis.com/en/pro-app/tool-reference/ready-to-use/itemdesc-generateorigindestinationcostmatrix.htm
[175] https://openrouteservice.org/
[176] https://www.google.com/maps

Results and Recommendations

Comparing OpenStreetMap and Esri Results. Table 11 presents comparative results of car routing between Esri (no departure time specified), OpenStreetMap, and Google. Results are presented for each O-D pair in terms of duration (minutes), route length (miles), and speed (mph). Table 12 presents similar results, but for trucks. As can be seen from the results, there are differences across all three data sources as each has its own network data and routing algorithms. However, OpenStreetMap results show average route speeds that are lower than would be expected (highlighted in red). This calls into question the accuracy of the OpenStreetMap data.

Table 11 Comparing OpenStreetMap and Esri results–Cars

		Esri, Cars, Average**			OpenStreetMap, Cars			Google*** (3:30 pm on 7/5)		
O*	D*	Minutes	Miles	MPH	Minutes	Miles	MPH	Minutes	Miles	MPH
4	1	45.59	36.12	47.53	59.00	38.90	39.56	51.00	35.29	41.52
4	3	51.48	40.23	46.89	59.00	43.50	44.23	53.00	40.82	46.22
4	2	76.84	59.32	46.32	113.00	62.32	33.09	89.00	60.02	40.47
2	3	33.79	22.01	39.08	64.00	21.75	20.39	46.00	22.74	29.66
2	4	75.61	57.36	45.52	113.00	62.20	33.03	87.00	63.38	43.71
2	1	99.92	75.59	45.39	143.00	47.66	20.00	111.00	76.43	41.31
3	2	34.38	22.01	38.41	64.00	21.75	20.39	46.00	22.74	29.66
3	4	51.50	38.50	44.86	59.00	43.56	44.30	53.00	43.56	49.31
3	1	75.81	56.73	44.90	89.00	56.86	38.33	77.00	56.73	44.21
1	4	47.10	38.25	48.72	59.00	39.08	39.75	50.00	35.29	42.35
1	3	75.91	56.77	44.88	89.00	56.92	38.37	78.00	57.41	44.17
1	2	101.26	75.86	44.95	143.00	47.66	20.00	114.00	77.05	40.55

Table 12 Comparing OpenStreetMap and Esri results–Trucks

		Esri, Trucks, Average**			OpenStreetMap, Trucks			Google*** (3:30 pm, 7/5/19)		
O*	D*	Minutes	Miles	MPH	Minutes	Miles	MPH	Minutes	Miles	MPH
4	1	46.45	38.09	49.20	63.00	35.42	33.73	51.00	35.29	41.52
4	3	52.42	43.52	49.82	64.00	40.20	37.69	53.00	40.82	46.22
4	2	77.77	62.61	48.30	119.00	59.03	29.76	89.00	60.02	40.47
2	3	33.79	22.01	39.08	66.00	21.75	19.77	46.00	22.74	29.66
2	4	76.55	62.46	48.95	120.00	62.20	31.10	87.00	63.38	43.71
2	1	111.90	85.30	45.74	148.00	75.50	30.61	111.00	76.43	41.31
3	2	34.38	22.01	38.41	66.00	21.75	19.77	46.00	22.74	29.66
3	4	52.45	43.60	49.88	64.00	43.56	40.84	53.00	43.56	49.31
3	1	87.80	66.44	45.40	92.00	56.86	37.08	77.00	56.73	44.21
1	4	47.10	38.25	48.72	63.00	35.42	33.73	50.00	35.29	42.35
1	3	87.40	66.63	45.74	93.00	56.92	36.72	78.00	57.41	44.17
1	2	112.76	85.71	45.61	148.00	75.75	30.71	114.00	77.05	40.55

*Source Table 11 and Table 12: EDR-EBP Analysis. *Origin and destination identification numbers correspond to the numbering in Figure 29. **Travel time with no departure time specified. ***Google has no mode specified but presumably defaults to car drive times.*

The Significance of Congestion. Table 13 compares car travel times and routes for each O-D pair between Esri's default or average routing with no departure time specified and results for a 9am Tuesday start time. The results show that while there are some differences in routing and travel times, congested conditions observed at 9 am in general to not have major impact on the analysis. This is not unexpected, given that rural areas are far less susceptible to congestion. Table 14 shows the same comparison for trucks. In the case of trucks, there is no different in routing at all in response to congestion, and only small differences in travel times. While there do appear to be minor effects from congestion, these effects do not appear significant enough to recommend that access measures be calculating at different times of day (e.g., access to jobs at peak and access for freight during off-peak) as this would multiply the number of calculations required by a significant amount.

Table 13 Comparing Congested to Average Travel Times in Esri–Cars

		(A) Esri, Cars, Average**			(B) Esri, Cars, 9 am, 5/14/19			(B) Minus (A)		
O*	D*	Minutes	Miles	MPH	Minutes	Miles	MPH	Minutes	Miles	MPH
4	1	45.59	36.12	47.53	46.60	36.12	46.51	1.00	0.00	-1.02
4	3	51.48	40.23	46.89	52.37	38.20	43.76	0.89	-2.03	-3.13
4	2	76.84	59.32	46.32	78.16	57.28	43.98	1.32	-2.03	-2.34
2	3	33.79	22.01	39.08	34.98	22.01	37.75	1.19	0.00	-1.33
2	4	75.61	57.36	45.52	78.44	52.90	40.46	2.83	-4.47	-5.06
2	1	99.92	75.59	45.39	104.09	66.03	38.06	4.18	-9.56	-7.33
3	2	34.38	22.01	38.41	34.53	22.01	38.24	0.16	0.00	-0.17
3	4	51.50	38.50	44.86	53.02	43.60	49.33	1.52	5.10	4.48
3	1	75.81	56.73	44.90	78.69	56.73	43.26	2.87	0.00	-1.64
1	4	47.10	38.25	48.72	47.57	38.25	48.24	0.47	0.00	-0.48
1	3	75.91	56.77	44.88	78.14	56.77	43.59	2.23	0.00	-1.28
1	2	101.26	75.86	44.95	103.94	75.86	43.79	2.68	0.00	-1.16

*Source: EDR-EBP Analysis. *Origin and destination identification numbers correspond to the numbering in Figure 29.*
***Travel time with no departure time specified.*

Table 14 Comparing Congested to Average Travel Times in Esri–Trucks

		(A) Esri, Trucks, Average**			(B) Esri, Trucks, 9 am, 5/14/19			(B) Minus (A)		
O*	D*	Minutes	Miles	MPH	Minutes	Miles	MPH	Minutes	Miles	MPH
4	1	46.45	38.09	49.20	47.62	38.09	47.99	1.17	0.00	-1.21
4	3	52.42	43.52	49.82	53.40	43.52	48.90	0.98	0.00	-0.92
4	2	77.77	62.61	48.30	79.19	62.61	47.44	1.42	0.00	-0.86
2	3	33.79	22.01	39.08	34.98	22.01	37.75	1.19	0.00	-1.33
2	4	76.55	62.46	48.95	78.64	62.46	47.66	2.09	0.00	-1.30
2	1	111.90	85.30	45.74	116.69	85.30	43.86	4.79	0.00	-1.88
3	2	34.38	22.01	38.41	34.53	22.01	38.24	0.16	0.00	-0.17
3	4	52.45	43.60	49.88	53.02	43.60	49.33	0.58	0.00	-0.54
3	1	87.80	66.44	45.40	91.03	66.44	43.79	3.23	0.00	-1.61
1	4	47.10	38.25	48.72	47.57	38.25	48.24	0.47	0.00	-0.48
1	3	87.40	66.63	45.74	88.55	66.63	45.14	1.15	0.00	-0.59
1	2	112.76	85.71	45.61	114.33	85.71	44.98	1.57	0.00	-0.63

*Source: EDR-EBP Analysis. *Origin and destination identification numbers correspond to the numbering in Figure 29.*
***Travel time with no departure time specified.*

Taking into Account Truck Restrictions and Route Preferences. Table 15 and Table 16 compare car and truck routes and travel times for the O-D pairs under average and congested conditions, respectively. While for many of the O-D pairs, the results are very similar, there are two pairs (four considered bi-directionally) that appear to have meaningful differences in car versus truck routes. The

Esri function used to generate these results outputs numerical results but does not produce and save the actual geometries of each path, thus preventing diagnostics of the different route choices of cars versus trucks in the Esri routing process. The nature of truck versus car routing merits further investigation and consideration in subsequent implementation of this study's recommendations.

Table 15 Comparing Car and Truck Routes and Times–Average

		(A) Esri, Cars, Average**			(B) Esri, Trucks, Average**			(B) Minus (A)		
O*	D*	Minutes	Miles	MPH	Minutes	Miles	MPH	Minutes	Miles	MPH
4	1	45.59	36.12	47.53	46.45	38.09	49.20	0.86	1.97	1.67
4	3	51.48	40.23	46.89	52.42	43.52	49.82	0.94	3.29	2.93
4	2	76.84	59.32	46.32	77.77	62.61	48.30	0.94	3.29	1.98
2	3	33.79	22.01	39.08	33.79	22.01	39.08	0.00	0.00	0.00
2	4	75.61	57.36	45.52	76.55	62.46	48.95	0.95	5.10	3.43
2	1	99.92	75.59	45.39	111.90	85.30	45.74	11.98	9.71	0.35
3	2	34.38	22.01	38.41	34.38	22.01	38.41	0.00	0.00	0.00
3	4	51.50	38.50	44.86	52.45	43.60	49.88	0.95	5.10	5.02
3	1	75.81	56.73	44.90	87.80	66.44	45.40	11.98	9.71	0.51
1	4	47.10	38.25	48.72	47.10	38.25	48.72	0.00	0.00	0.00
1	3	75.91	56.77	44.88	87.40	66.63	45.74	11.50	9.86	0.86
1	2	101.26	75.86	44.95	112.76	85.71	45.61	11.50	9.86	0.66

*Source: EDR-EBP Analysis. *Origin and destination identification numbers correspond to the numbering in Figure 29.*
***Travel time with no departure time specified.*

Table 16 Comparing Car and Truck Routes and Times–Congested Start Time

		(A) Esri, Cars, 9 am, 5/14/19			(B) Esri, Trucks, 9 am, 5/14/19			(B) Minus (A)		
O*	D*	Minutes	Miles	MPH	Minutes	Miles	MPH	Minutes	Miles	MPH
4	1	46.60	36.12	46.51	47.62	38.09	47.99	1.03	1.97	1.48
4	3	52.37	38.20	43.76	53.40	43.52	48.90	1.03	5.33	5.14
4	2	78.16	57.28	43.98	79.19	62.61	47.44	1.04	5.33	3.46
2	3	34.98	22.01	37.75	34.98	22.01	37.75	0.00	0.00	0.00
2	4	78.44	52.90	40.46	78.64	62.46	47.66	0.20	9.56	7.19
2	1	104.09	66.03	38.06	116.69	85.30	43.86	12.60	19.27	5.80
3	2	34.53	22.01	38.24	34.53	22.01	38.24	0.00	0.00	0.00
3	4	53.02	43.60	49.33	53.02	43.60	49.33	0.00	0.00	0.00
3	1	78.69	56.73	43.26	91.03	66.44	43.79	12.34	9.71	0.54
1	4	47.57	38.25	48.24	47.57	38.25	48.24	0.00	0.00	0.00
1	3	78.14	56.77	43.59	88.55	66.63	45.14	10.42	9.86	1.55
1	2	103.94	75.86	43.79	114.33	85.71	44.98	10.39	9.86	1.19

*Source: EDR-EBP Analysis. *Origin and destination identification numbers correspond to the numbering in Figure 29.*
***Travel time with no departure time specified.*

4.6 Time Decay Function and Mapping

Purpose

The majority of this study's suggested core and complementary metrics would be calculated on the basis of a time decay function. This demonstration develops a map for one exemplary metric. This is intended to give Appalachian states, regions, and local governments the opportunity to assess the adequacy of using and mapping metrics with time decay functions.

Methodology

We calculate and map an *access to jobs* metric, according to the following methodology:

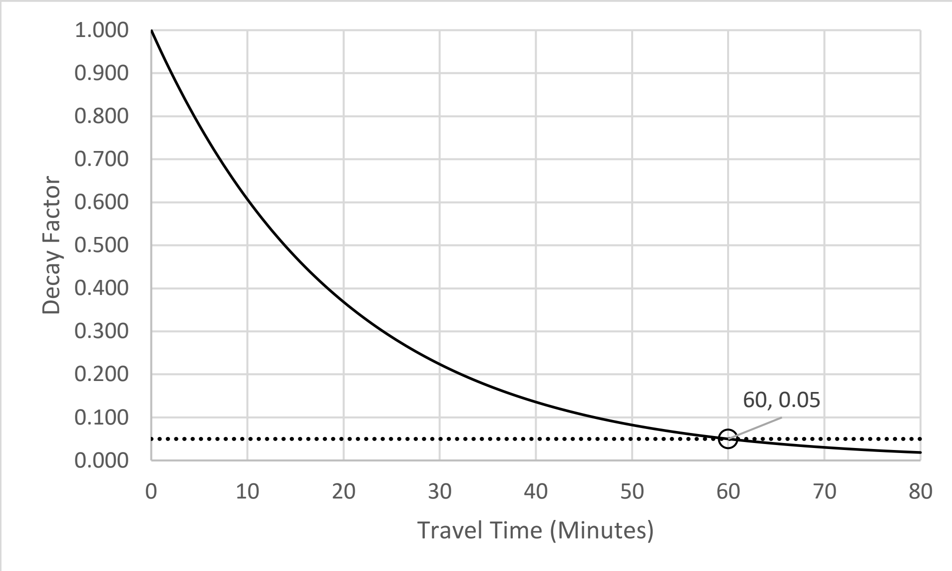
Calibrating a decay function to fit data from the 13 Appalachian States. The following formula is used to develop the decay function:

$$A_i = \sum_{j=1}^{n} D_j e^{-\beta t_{ij}}$$

Where A_i is the accessibility of zone i to all destinations in other zones (j) and t_{ij} is the travel time between zone i and zone j. D_j is a measure of the importance of destinations in zone j. Here β determines the shape of the decay function that mediates the opportunity offered by the destinations. Where travel time is zero, $e^{-\beta t_{ij}} = 1$, meaning the full measure of the importance of the destination is counted. For any travel time greater than 1, that factor becomes a fraction reducing the weight given to the destination opportunity.

Our approach to choosing the parameter β is to find the 95th percentile of travel time for the Region and mode of interest and then set β such that if t_{ij}=t_{95}, then $e^{-\beta t_{ij}} = 0.05$. Using data from the National Household Travel Survey for all 13 Appalachian states, t_{95} is 60 minutes for car mode, meaning 95% of trips are less than 60 minutes. β therefore is 0.04993 in our formula. Figure 30 illustrates this decay function.

Figure 30 Negative exponential function



Source: EDR Group (now EBP) analysis using data from the National Household Travel Survey.

Destination Data. The importance of each destination (D_j as described above) is measured as the total number of jobs in each block group. This demonstration analysis uses block group data that is aggregated from the block level Workplace Area Characteristics of the LEHD Origin-Destination Employment Statistics (LODES).[177]

Centroids. Access to jobs is measures from the perspective of people, to the location of jobs. Therefore, origins are population-weighted centroids and destinations are employment-weighted centroids, with replacement of geometric centroids as necessary according to the methodology described in Chapter 4.3 above.

Travel Times. Travel times were estimated using the *Generate Origin Destination Cost Matrix* tool of Esri's ArcGIS online.[178] The tool was used to calculate car drive times, without specifying a specific time of day for the calculations.

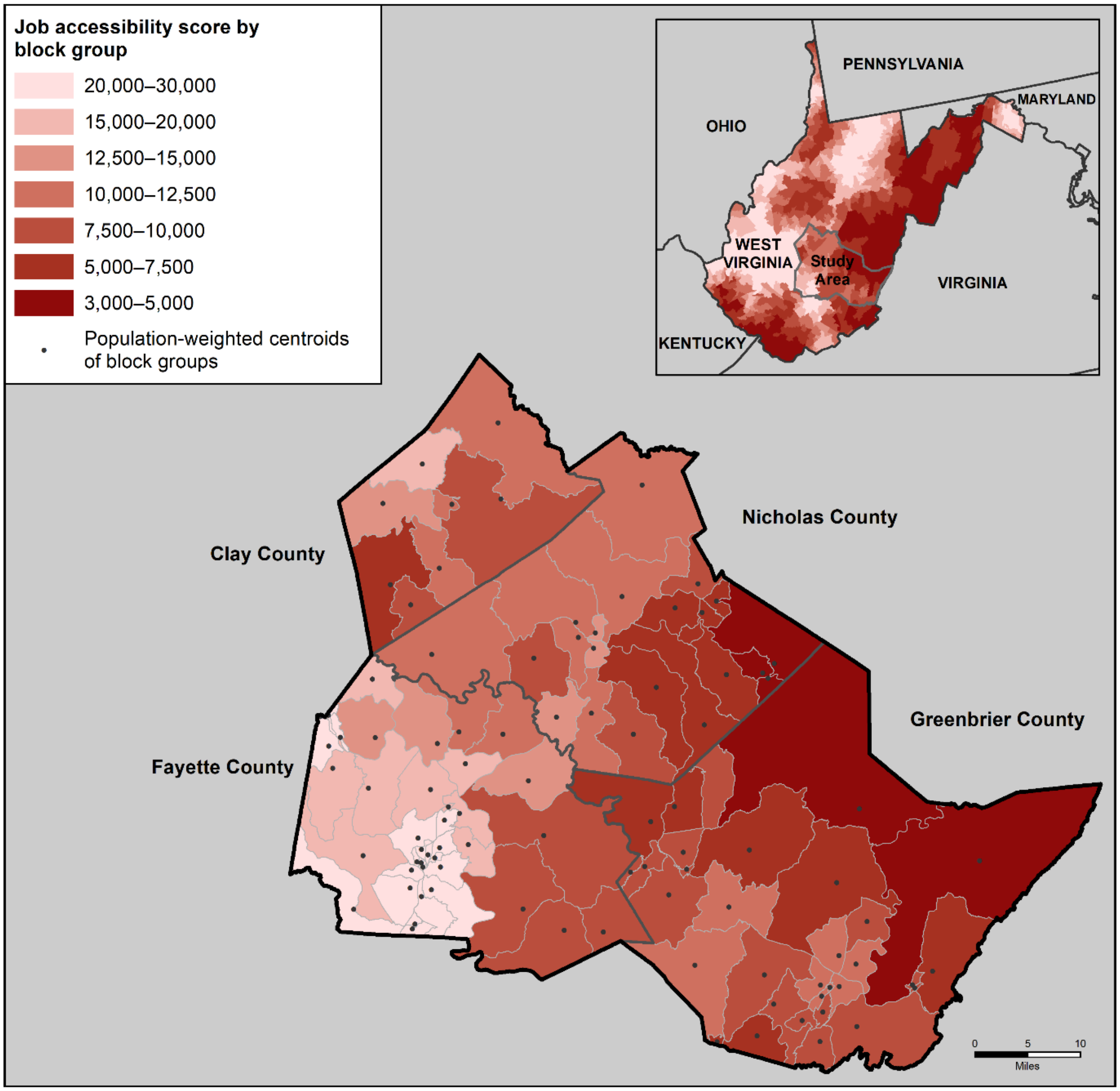
Results and Recommendations

Figure 31 shows the results of the analysis. The larger map presents results for our specific test areas. The smaller inset map shows how this is contextualized within the broader geography of West Virginia. As can be seen from the maps, job accessibility within the test area is influenced both by the location of employment centers within the selected four counties, as well as by the major job centers outside the test area. For example, higher jobs accessibility scores in the southern part of Fayette County reflects both the concentration of jobs in Oak Hill, WV (inside the test area), and the influence of additional jobs just to the south outside of both Fayette County and the test area, in Beckley, WV.

[177] https://lehd.ces.census.gov/data/
[178] https://pro.arcgis.com/en/pro-app/tool-reference/ready-to-use/itemdesc-generateorigindestinationcostmatrix.htm

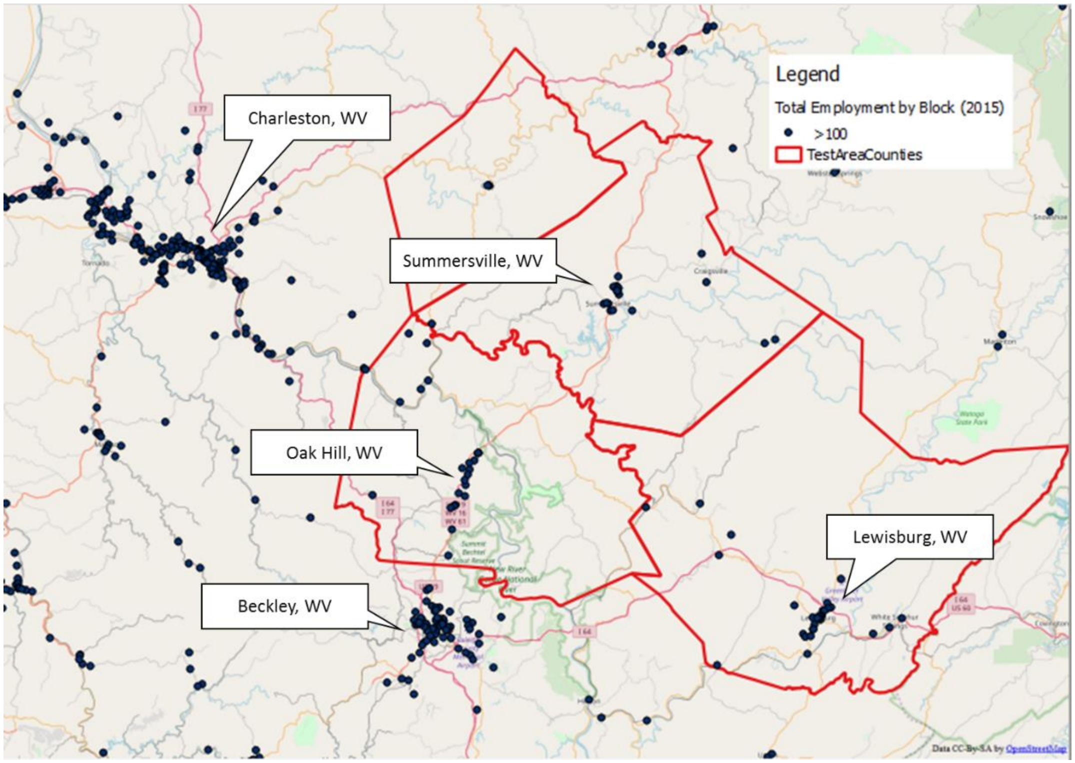
Similarly, job accessibility in the western part of the test area also reflects the concentration of jobs in Charleston, WV which lies outside the Test Area. Figure 32 is provided for reference to show the location of employment centers, using the LEHD data by block groups.

Figure 31 Illustration of Job Accessibility Using a Time Decay Function (Sample Map)



Source: EBP analysis using data from LEHD, the Census extracted using IPUMS NHGIS, and ArcGIS online.

Figure 32 Employment Centers–Census Blocks with More than 100 Employees



Source: EDR Group (now EBP) mapping using data from OpenStreetMap, LEHD, and IPUMS NHGIS.

The demonstration illustrates how time decay access measures can be developed and communicated to highlight in a comparative fashion where access is more or less constrained. When implementing this study's recommended metrics, we suggest giving further consideration to the following aspects of calculation and visualization:

- Should the decay parameter β vary by trip purpose/type of access?
- If access measures are to be weighted based on the relevant user group (e.g., working age population) as put forth in Chapter 3.5, should this be what is mapped, or is there value to mapping weighted and unweighted results?
- What types of coloring/classification schemes are most effective at communicating the results? Should they be comparable across access measures that have different units?
- Within the context of an interactive tool, should (and could) classification schemes vary dynamically based on the geographic extent of results shown, or should they be standardized across all 13 states? Different areas of the 13-state region will have varying minimum and maximum accessibility scores so depending on the classification scheme, "low accessibility" areas can be considered relative to the full 13-state range or relative to the (smaller) geographic extent being considered.

4.7 Nearest Destination Metric and Mapping

Purpose

As a contrast to the time decay function shown in Chapter 4.6, using a metric that considers only the travel time to the nearest destination of its kind should still be considered for select types of access. Mapping the metric will allow the comparison with a metric defined by a time decay function (see above). This provides an exemplary map for one metric of this type.

Methodology

We calculate and map an *access to trauma centers* metric, according to the following methodology:

Destination Data: Level 1 and 2 trauma centers located within the vicinity of our test area were identified by address, using the American Trauma Society's "Find Your Local Trauma Center" tool[179], as shown in Table 17. These addresses were then geocoded using ArcGIS online.

Table 17 Level 1 and 2 Trauma Centers Near Test Area

Trauma Centers Level 1–2	Address	City	State	ZIP
CAMC–General Hospital	501 Morris Street	Charleston	WV	25301
Cabell Huntington Hospital–Tri-State Trauma Center	1340 Hal Greer Boulevard	Huntington	WV	25701
St. Mary's Medical Center–Tri-state Trauma Center	2900 First Avenue	Huntington	WV	25702
Carilion Roanoke Memorial Hospital	1906 Belleview at Jefferson Street	Roanoke	VA	24014

Source: American Trauma Society. Find Your Local Trauma Center.
https://www.amtrauma.org/page/findtraumacenter

Centroids. Access to trauma centers is a population-oriented measure. Therefore, the centroids from which travel times to trauma centers are measured are population-weighted block group centroids (with corrections to geometric centroids as necessary according to the methodology described in Chapter 4.3 above).

Travel Times. Travel times were calculated using the *Find Closest Facilities* tool of ArcGIS online. The tool was used to calculate car drive times, without specifying a specific time of day for the calculations.

Results and Recommendations

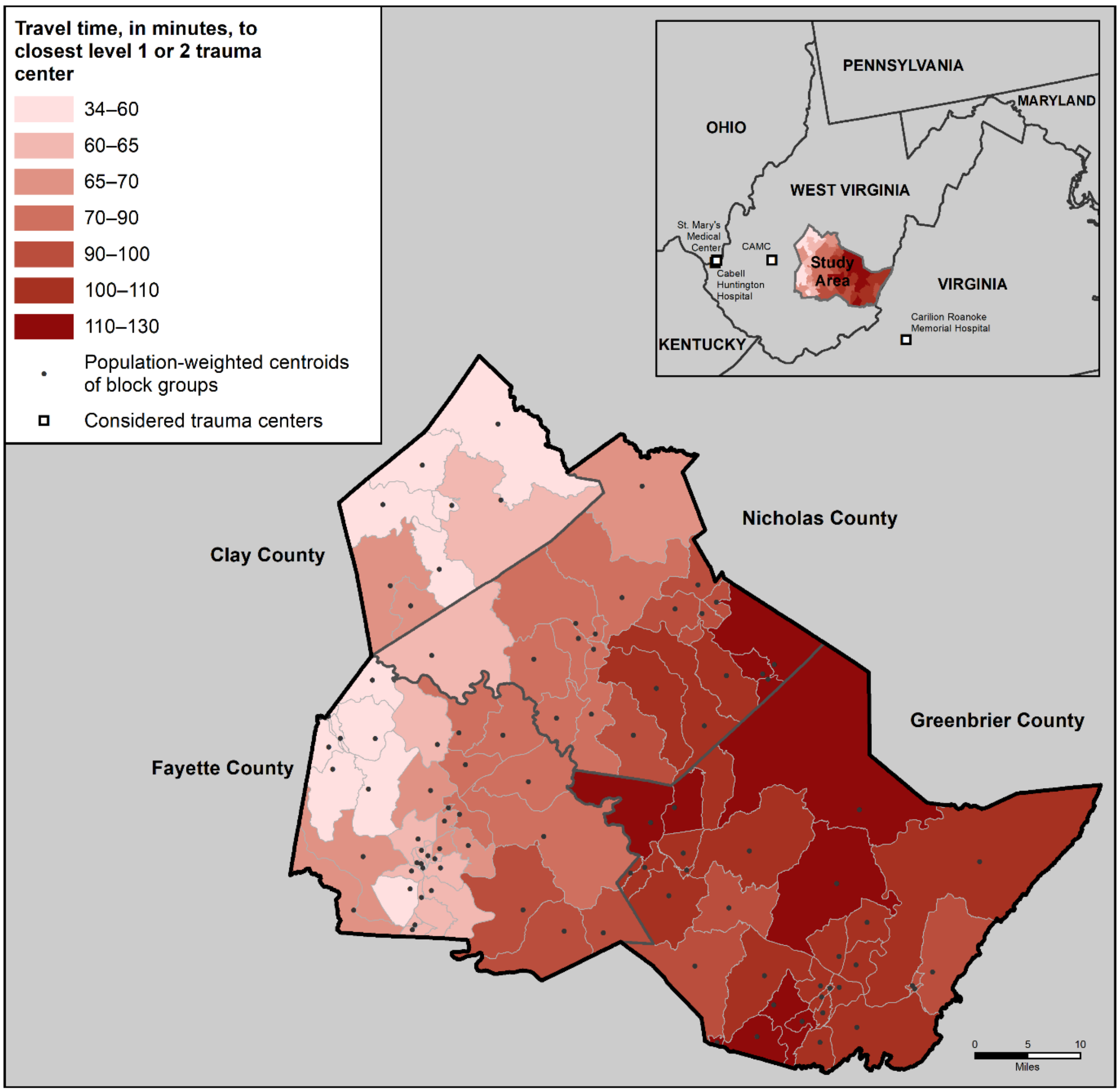
Figure 33 maps travel time to the closest trauma center within our test area. The areas with the best access are to the west, based on proximity to CAMC located in Charleston, WV. On the eastern side of the test area, there are some block groups that are closer to Carilion Roanoke Memorial Hospital. Note that while the inset map shows all of West Virginia, it only considers the four trauma centers

[179] https://www.amtrauma.org/page/findtraumacenter

identified as being relevant to the test area, all of which are situated outside of the study area. A full implementation of this measure would involve mapping other relevant trauma centers as well.

The demonstration illustrates how a nearest destination metric can be developed and mapped to show where access is more or less constrained. When implementing this research, further consideration should be given to visualization issues such as whether to show both weighted and unweighted results (by user group counts) and the most effective coloring/classification schemes. These visualization issues are the same for a nearest destination metric as previously described in Chapter 4.7 *Results and Recommendations.*

Figure 33 Travel Time to the Closest Level 1 and 2 Trauma Center (Sample Map)



Source: EBP analysis using data from the Census, extracted using IPUMS NHGIS, the American Trauma Society, and ArcGIS online. Note that all four trauma centers considered for this sample map are located outside of the study area.

4.8 Concept for Representing Transit

Purpose

Even though driving is the predominant mode for most people in the Region, we consider other modes as well to paint a more complete picture of access in Appalachia. The situation of people with no car available should also be part of the story told by this study. However, data about other modes, especially transit, is at this moment for large parts of rural Appalachia not available in the necessary level of detail (see Chapter 3.3). The challenge of using data for transit is twofold: (1) Transit in rural areas is not always provided as a scheduled fixed route service that allows point-to-point travel time calculations and (2) where there is scheduled fixed route service provided by small transit agencies, the schedule data is not always available in GTFS format.

Concept

We distinguish four tiers of transit services:

- Tier one: For fixed-route transit with schedules, travel time information from zone to zone and expected wait times based on frequency of service can in theory be developed, either in an automated fashion with GTFS or in a more manual way.
- Tier two: For fixed-route transit without schedules (on-demand), travel times should be attainable, but we will not have trip frequencies.
- Tier three: For on-demand transit for any purposes, we will only have coverage information.
- Tier four: Specific on-demand transit for specific purposes (e.g., NEMT) could have a mixture of information.

For a full representation of transit options, we will have to put up with some level of heterogeneity in the way transit is represented.

ARC is in the process of commissioning a study about transit in Appalachia, which among other tasks will conduct an inventory of transit in Appalachia. This will be major source of information about transit characteristics that can be used when implementing the recommendations from this study.

Recommendations

We suggest working with transit information of different kinds to generate zone-to-zone travel times, as summarized in Table 18 below.

Table 18 Kinds of Transit Service and Zone-to-Zone Travel Time Considerations

Kinds of Transit Service	Zone-to-Zone Travel Time Consideration
• Tier one–fixed-route with schedule and with GTFS data	Automated generation from GTFS data, also reflecting frequency, access, and egress
• Tier one–fixed-route with schedule and without GTFS data	Non-automated generation, also reflecting frequency, access, and egress
• Tier two–fixed-route transit without schedule (on-demand).	Non-automated generation, reflecting average waiting times, access, and egress
• Tier three–on-demand transit for any purposes (operated by public or private provider)	Use of zone-to-zone driving times (passenger cars), reflecting average waiting times
• Tier four–specific on-demand transit for specific purposes (e.g., NEMT[180] trips provided by health care providers, local government agencies or NGO)	

More than one of these forms of transit may be available in one place in Appalachia. Once ARC's inventory mentioned above is conducted, a method to superimpose travel time information from multiple transit services can be developed.

4.9 Concept for Aggregating Modal Options into one Metric

Purpose

This study is aiming at giving a picture of accessibility in Appalachia that is as complete as possible. Various user groups and destinations are differentiated for that purpose to develop a set of accessibility metrics that together portray different people and businesses accessing different destinations. Serving the same purpose, this Chapter describes a way to integrate various modal options in the individual multimodal metrics for passenger transportation. While most people can rely on a car to which they have access for their trips, this multimodal perspective should reflect that not everybody can. In households with no cars or too few cars, household members have to rely on transit, where available, and other alternate options.

[180] Non-Emergency Medical Transportation

Concept

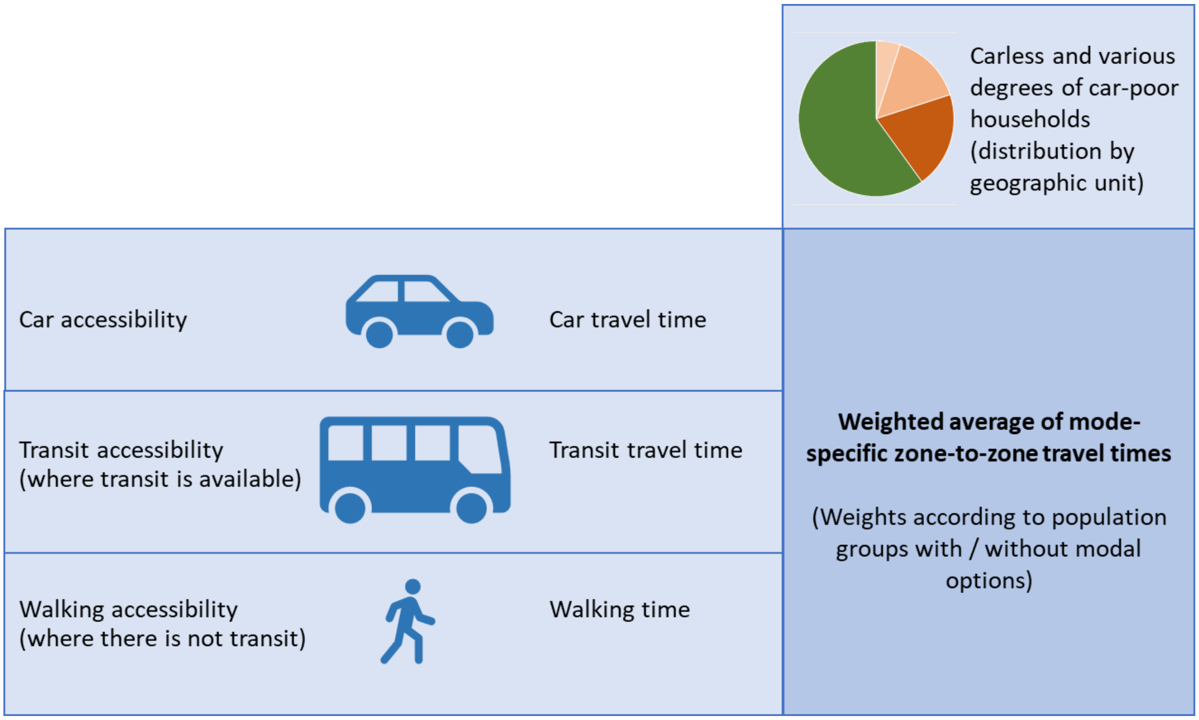
While the user groups and the destinations are assumed independent of modes, the measure for impedance, here travel time, is not. Travel times are determined for each passenger mode (car, transit where available, walking) individually but they are not all mapped individually. We suggest making use of 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 based on these accessibility metrics 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.[181] Information about carless or various degrees of car-poor households may portray the *level of car availability by geographic area* (Census block group).
- *Multimodal accessibility* will represent the third piece of information that can be provided. It involves 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 (see Figure 34).

It should be noted that the use of walking as the fallback mode obviously 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 (car-sharing, ride hailing, 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.

[181] ARC is working on an analysis to determine not only carless, but also "car-poor" households in Appalachia. Information about the share of carless households by geographic area is available from the American Community Survey (ACS).

Figure 34 Aggregating Modal Options into One Multimodal Travel Time



Source: EDR Group (now EBP) graphic

Recommendations

We suggest developing aggregate multi-modal accessibility metrics besides the mode-specific metrics for cars and transit. Their calculation is based on weighted averages of mode-specific travel times. The weights are determined by the geographic unit's share of carless and car-poor households.

5 Conclusions for Accessibility Analysis in Appalachia

5.1 Recommended Metrics and Vision

This research study was designed to establish a comprehensive understanding of transportation-related access in Appalachia. While overall access to jobs is a significant concern, the study concluded that there are many other aspects of access that should also be considered. For that reason, we recommend that future efforts to measure accessibility should also include (see Chapter 3.5):

(1) more differentiated user groups

(2) a variety of destinations

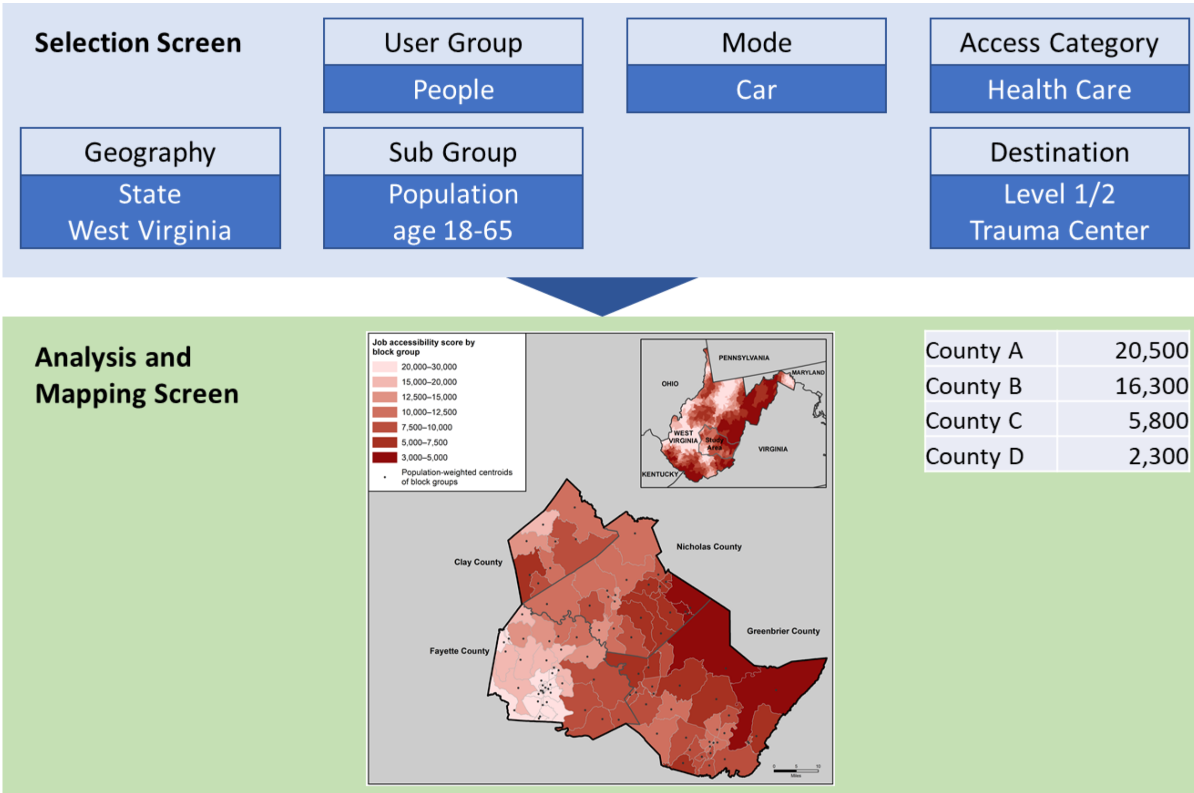
(3) more modes than just driving

Table 19 Set of Accessibility Metrics, by User Group (Not Showing Subsets of User Groups)

Businesses–Access to …	
B1. Labor	
B2. Supply chain	
B3. Delivery	**Consumers**
B4. Intermodal connectivity	**a) Rail facility**
	b) Port
	c) Airport
People–Access to …	
P1. Job	
P2. Education	**College**
P3. Health care	**a) Primary care**
	b) Trauma center
	c) Addiction treatment center
P4. Town centers	
P5. Tourist destination	
Technology–Access to …	
T1. Mobile Broadband (i.e., Cell Phones)	
T2. Fixed Broadband (i.e., at home)	

The proposed vision is to develop an **Analysis and Mapping Tool for *Access in Appalachia*** that is capable of producing maps and tables that can show any of the recommended metrics for any area within the 13 Appalachian states. With this tool, users would be able to select a geography and a metric (user group, mode and destination) and then get the respective map and data in tables (Figure 35).

Figure 35 Schematic Overview of Analysis and Mapping Tool (Example)



Source: EDR Group (now EBP) graphic

The metrics are separated into sets of **core metrics** and supporting **complementary metrics**. The recommended core metrics are listed in Chapter 3.5.

5.2 Implementation

Overview and Tasks

This study analyzed existing research and the state of practice in Appalachia in order to define accessibility in ways relevant for Appalachia and then develop a methodology for measuring its various facets. For a few important open questions, a preliminary proof of concept analysis was conducted. The recommended set of metrics and the implementation vision are presented as part of this report.

In this Chapter, we outline an approach for building the envisioned *Access in Appalachia* tool. We provide a comprehensive set of next steps that would lead to development of a fully integrated measurement system. However, this approach could also be phased to begin with an initial set of metrics that are of the most immediate interest to Appalachian stakeholders, followed by subsequent rollout of additional access measures.

We suggest structuring implementation in the following tasks:

1. Proof of Concept for Analysis and Mapping Tool (for samples)–Pilot Application
2. Data Collection
3. Finalizing Methodology
4. Data Processing
5. Data Analysis and Scaling
6. Tool Automation
7. Documentation

The following subsections briefly describe the efforts that are expected to be part of each of these tasks. In addition to the steps outlined below, implementation would also require cooperation with Appalachian stakeholders to ensure that appropriate testing protocols and engagement with end-users is part of the process.

1–Proof of Concept

While some initial proof of concept analyses were conducted in Chapter 4 to develop and validate recommendations, a full proof of concept is recommended at the beginning of implementation. We suggest selecting one metric for which all data is publicly available and known. A candidate would again be the metric "access to jobs", as in the mapping exercise presented in Chapter 4.6. The necessary data for this metric (population, jobs, zone-to-zone travel times for passenger cars[182]) would be collected and processed for the entire 13-state area. An initial selection interface and mapping capability would be developed to allow for testing.

2–Data Collection

We have described potential data sources and made recommendations for many of the public or proprietary data to be used for each of the metrics (see Appendix II). Table 20 lists widely available (mostly public) data sources. This task includes contacting owners of any proprietary data we suggest using and making final data selection choices based on availability and cost.

[182] Travel time for transit would not yet be processed. Transit will only be included after ARC's Transit Inventory project will have reached a sufficient level of progress.

Table 20 Data Requirements and Anticipated Collection Effort

Businesses–Access to …		Presumable Data Source	Collection Effort
Businesses		United States Census Bureau	-
B1. Labor		United States Census Bureau	-
B2. Supply chain		United States Census Bureau	-
B3. Delivery	**Consumers**	United States Census Bureau	-
B4. Intermodal connectivity	**a) Rail facility**	Oak Ridge National Labs (ORNL) Transportation Networks; FAF etc.	-
	b) Port		
	c) Airport		
People–Access to …		**Presumable Data Source**	**Collection Effort**
People		United States Census Bureau	-
P1. Job		United States Census Bureau	-
P2. Education	**College**	National Center for Education Statistics (NCES, public)	Data request (proprietary)
P3. Health care	**a) Primary care**	Health Resources and Services Administration	-
	b) Trauma center	American Trauma Society's "Find Your Local Trauma Center" tool	Data request (proprietary)
	c) Addiction treatment center	Substance Abuse and Mental Health Services Administration (SAMHSA)	Data request (proprietary)
P4. Town centers		LEHD OnTheMap (Census)	-
P5. Tourist destination		National Park Service (NPS), State Agencies	Data collection in 13 states necessary
Technology–Access to …		**Presumable Data Source**	**Collection Effort**
T1. Mobile Broadband (i.e., Cell Phones)		FCC 20Th Mobile Wireless Report	-
T2. Fixed Broadband (i.e., at home)		FCC Fixed Broadband Deployment	-
Travel Time Data		**Presumable Data Source**	**Collection Effort**
Passenger Cars		Esri ArcGIS	Data cost (credits)
Trucks (potentially)			
Transit		Various (GTFS, ARC inventory)	Data inventory (ARC)

3–Finalizing Methodology

Even though most of the methodologies have been developed in this study, a few methodological choices remain to be made. Most importantly, this step of implementation should include refining the functional form of decay functions (see Chapter 3.4). Additionally, this task should make a final decision about whether to separately calculate zone-to-zone travel times for trucks (see Chapter 4.5).

4–Data Processing

There are two areas for which major data processing efforts are expected:

- Travel Times: Centroids for population and employment will have to be determined for each geographic unit (block group). Travel times are calculated zone-to-zone for cars, trucks and (where available) transit. For metrics that measure the travel times to the nearest destination of a kind (e.g.,, trauma centers), a process should be developed to determine the nearest location without having to calculate travel times to all potential locations.[183]

- Location Data: Destinations with discrete locations like hospitals or colleges will have to digitized and mapped.

5–Data Analysis and Scaling

Scales for each of the metrics will have to be preset to be able to compare and assess accessibility calculation results. For that purpose, each core metric must be calculated for the entire 13-state area. The results will show the ranges of values for each of the metrics and will allow the user to set thresholds for categories along the scale.

6–Tool Automation

The tool should produce tables and maps as outputs automatically for any geography and any core or complementary metric. This capability has to be built in and tested.

7–Documentation

We suggest two volumes of documentation: (1) a technical report about the analysis and findings of implementation and (2) a user manual for the analysis and mapping tool.

[183] As we suggest using Esri ArcGIS for determining travel times, this step is also relevant for the cost involved in using ArcGIS credits.

Appendix I–List of Interviewees

Interviewee(s)	Organization	Sector	Date
Heather Rose, Jasmy Methipara	FHWA–Office of Policy	USDOT	12/19/2018
Chad Tucker	VDOT	State DOT	01/09/2019
Jason B. Schronce	NCDOT	State DOT	12/20/2018
John Moore	KYTC	State DOT	12/19/2018
Paul Degges	TDOT	State DOT	12/21/2018
Jim Gates	ODOT	State DOT	12/20/2018
Wayne Strickland, Cristina Finch	Roanoke Valley-Alleghany Regional Commission	Local Development Districts and MPOs	12/18/2018
Rose Bauguess	Southwestern NC COG	Local Development Districts and MPOs	12/19/2018
Jeannette Wierzbicki	Ohio Mid-Eastern Governments Association	Local Development Districts and MPOs	12/21/2018
Christ Chiles	KYOVA Interstate Planning Commission (WV, KY, OH)	Local Development Districts and MPOs	12/17/2018
Bill Austin	Morgantown, WV MPO	Local Development Districts and MPOs	12/12/2018
Annaka Woodruff	Georgia	ARC State Program Managers	12/18/2018
Olivia Collier	North Carolina	ARC State Program Managers	12/12/2018
Brooxie Carlton	Tennessee	ARC State Program Managers	12/12/2018

Interview Guides

A. Introduction

“Access” means the ability of residents and businesses to reach desired opportunities and services. For residents, this may include access to employment, education, medical facilities, and recreation. For businesses, opportunities and services may include employees, suppliers, and markets (domestic and international).

Through this study, ARC hopes to define and measure access, compare quality and level of access among Appalachian communities, consider how access relates to socioeconomic outcomes, and ultimately help practitioners use access metrics to better prioritize transportation (or other public) investments.

1. Do you have any questions about the purpose and direction of the project at this point?
2. Could you describe in your own words your perspective towards accessibility in your work / role?

B. Definition of Accessibility

We are defining accessibility along three dimensions: User Group, Attractions/Destinations and Network Availability and Performance. The definition and the subsequent metrics we develop over the course of this project should be as specifically tailored to the Appalachian Region as possible.

Dimensions of Accessibility Definition

User Group	Attractions/Destinations	Network Availability and Performance
Access for whom/from where?	Access to where/what? How attractive?	Are connections available? At what cost and along which network?

User Groups (people and businesses): Which user groups do you think are especially important to include in our study? Do you think it is especially important to analyze access for subgroups, like people below the poverty line or without access to a car, or specific kinds of businesses? How about access to public transit?

1. Attractions / Destinations: Access to where / what is critically important for people and businesses in Appalachia?
2. Network Availability and Performance: Which specific features of the network availability and performance in the Appalachian Region are especially important? How does geographic isolation play into this?

C. Responses to Accessibility Challenges

1. What do you consider to be a “reasonable” level of access? Have you ever tried to measure this?
2. What is/should be the role of transportation in providing access?
3. How does access affect socioeconomic status?
4. How can/should transportation policy address issues of access?

D. Sources / Practice

For all:

1. Are you aware of sources / research that are critically important to this study?

For FHWA:

2. Are you aware of any specific metrics from research or practice, which could be useful for Appalachia?

For state DOTs:

3. Which metrics are used in your state to measure accessibility in mostly rural areas? For which purpose? (Infrastructure prioritization, grant program, etc.)
4. Which metrics would you like to see in use?

For economic development agencies:

5. Which are the metrics you are aware of that are used by practitioners?
6. Which metrics are especially important because they are strongly related to economic outcomes?

Appendix II–Data Availability Assessments

Population and Employment Data

Name of Data Source	Type	Geographic Detail	Year	Data Detail	Public or Proprietary?	Other Notes	Link/Path
POPULATION							
American Community Survey (ACS)	Census data	State, county, sub-county, census tract, census block group, place, ZIP code	2017	Age, race, sex, poverty status, educational attainment, vehicle availability etc.	United States Census Bureau (Public)	Annual Population Estimates	https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Public Use Microdata Sample (PUMS)	Census data	People, households, organized by states	2017, 2013-17	Full level of detail from ACS questions	United States Census Bureau (Public)	PUMS contains a sample of actual responses to the ACS.	https://www.census.gov/programs-surveys/acs/data/pums.html
EMPLOYMENT							
Quarterly Census of Employment and Wages (QCEW)	Census data	County, MSA, state	3/2018	Count of employment and wages by Industry and ownership	Bureau of Labor Statistics (Public)	Reported by employers	https://www.bls.gov/cew/
County Business Patterns (CBP)	Census data	County, ZIP code	2016	Industry, employment, size class	United States Census Bureau (Public)		https://www.census.gov/programs-surveys/cbp.html
Longitudinal Employment Household Dynamics (LEHD)	Employment and household data	State, county			Public		https://lehd.ces.census.gov/
Infogroup	Business Data	Individual locations		Industry, size	Proprietary (for-profit)		https://www.infogroup.com/data

Additional Destination Data

Name of Data Source	Type	Geographic Detail	Year	Data Detail	Public or Proprietary?	Other Notes	Link/Path
COLLEGES							
Integrated Postsecondary Education Data System (IPEDS)–College Map	College location data (map)	Individual locations	Current (2019)	Filtering by public/private, major, state, distance, degree, tuition and more	National Center for Education Statistics (NCES, public)		https://nces.ed.gov/ipeds/CollegeMap/
College Navigator, National Center for Education Statistics (NCES)	College location data (query, list)	Individual locations	Current (2019)	State, type (e.g., 2-year public, 4-year private), degrees offered, net price	National Center for Education Statistics (public)	Multiple states can be selected, and filters set, locations in map.	https://nces.ed.gov/collegenavigator/
CareerOneStop	College location data (query, list)	Individual locations	Current (2019)	Information about specific colleges; no filter options, but sorting by location or program	Proprietary, publicly sponsored	Uses data from IPEDS; Sponsored by the United States Department of Labor	https://www.careeronestop.org/FindTraining/find-training.aspx
PRIMARY CARE							
Primary Care Physician Mapper	National Provider Identifier (NPI)–map	National scale, density by state, county, or census tracts for metropolitan areas	2015	Physicians in approx. 15 categories; population details by geographic area	Robert Graham Center (proprietary)	National Provider Identifier (NPI) is the data source, maintained by the Centers for Medicare and Medicaid Services (CMS).	https://www.graham-center.org/rgc/maps-data-tools/interactive/primary-care-physician.html
HRSA Data Warehouse	Find a Health Center–map	National scale, individual locations	Current (2019)	Only one category; no differentiation by size	Health Resources and Services Administration (public)		https://findahealthcenter.hrsa.gov/
American Medical Association (AMA)	Doctor Finder	National scale, individual locations	Current (2019)	Contains physicians who are AMA members, different categories	American Medical Association (AMA) (proprietary)	Requires registration	https://doctorfinder.ama-assn.org/doctorfinder/

Name of Data Source	Type	Geographic Detail	Year	Data Detail	Public or Proprietary?	Other Notes	Link/Path
Health Landscape	Interactive web-based analysis and mapping tool	County level or for (geographic or other) communities	Current state (various sources)		American Academy of Family Physicians (proprietary)	Various sources of health, socio-economic and environmental information	https://www.healthlandscape.org/
Uniform Data System (UDS)	Mapping and decision-support tool	National scale, individual locations, and population characteristics by area	Current state	Driven primarily from health center patient location data within the Uniform Data System (UDS)	American Academy of Family Physicians (proprietary)	Collaboration between Bureau of Primary Health Care (BPHC), the American Academy of Family Physicians (AAFP), and multiple companies; requires registration	https://www.udsmapper.org/index.cfm
Health Center Delivery Sites	Maps	State maps	2016	Main organizations and delivery sites	National Association of Community Health Centers (proprietary)		http://www.nachc.org/research-and-data/state-level-data-maps/
Rural Health Information Hub (RHIhub)	Federally Qualified Health Centers Sites Outside of Urbanized Areas– map	National scale, individual locations	Current (2019)	Only one category; Data source: data.HRSA.gov, United States Department of Health and Human Services	RHIhub (proprietary, but public data)	The designation itself already includes location considerations, which have accessibility in rural areas in mind.	https://www.ruralhealthinfo.org/rural-maps/mapfiles/federally-qualified-health-centers.jpg?v=1
TRAUMA CENTERS							
Trauma Center Digital Map, Trauma Center Association of America	Trauma Center location data (map)	National scale, individual locations	Current state (various sources)	Trauma Centers by Adult and Peds and by level (I-V for adults, I-IV for peds)	Fortress Maptive–Mapping services (proprietary)	Includes polygon tool to look at a given region and Google routing tool to give directions to Trauma Centers.	https://fortress.maptive.com/ver4/TCAA

Name of Data Source	Type	Geographic Detail	Year	Data Detail	Public or Proprietary?	Other Notes	Link/Path
American Trauma Society (ATS)	Trauma Center location data (map)	National scale, individual locations	2017	Trauma Center by level (I–V)	American Trauma Society (proprietary)	Includes polygon tool to look at a given region and Google routing tool to give directions to Trauma Centers. Source: 2017 ATS-TIEP	https://www.amtrauma.org/page/findtraumacenter
Rural Health Information Hub (RHIhub)	Critical Access Hospitals (CAH)–map	National scale, individual locations	Current (2019)	Only one category (CAH); Data source: data.HRSA.gov, United States Department of Health and Human Services	RHIhub (proprietary)	• Conditions to obtain CAH designation consider already accessibility aspects. • 25 or fewer acute care inpatient beds • More than 35 miles from another hospital (exceptions may apply) • Average length of stay of 96 hours or less for acute care patients • 24/7 emergency care services	https://www.ruralhealthinfo.org/rural-maps/healthcare-facilities
	Rural Health Clinics (RHC)–map	National scale, individual locations	Current (2019)	Only one category (RHC); Data source: data.HRSA.gov, United	RHIhub (proprietary)	The main purpose of the designation is to receive enhances	https://www.ruralhealthinfo.org/rural-maps/mapfiles/r

Name of Data Source	Type	Geographic Detail	Year	Data Detail	Public or Proprietary?	Other Notes	Link/Path
				States Department of Health and Human Services		reimbursement rates for providing Medicare and Medicaid services. RHCs must be located in rural, underserved areas, a condition which represents already accessibility aspects. They are required to use a team approach of physicians working with non-physician providers.	ural-health-clinics.jpg?v=1
ADDICTION TREATMENT CENTERS							
Medication-Assisted Treatment Facility Maps (MAT). Potential Areas for Addressing Service Gaps for Opioid Treatment	Maps to show service gaps	National scale, sub-county detail in maps by state	Various years	Differentiation between optimal (five quintiles) and non-optimal areas, by state	Substance Abuse and Mental Health Services Administration (SAMHSA, public)	Sources: Drug Use: NSDUH (2012) Facilities: SAMHSA (2016) Population: ACS 5-year average (2010-2014)	https://www.samhsa.gov/data/report/medication-assisted-treatment-facility-maps-mat
Substance Abuse and Mental Health Services	Location map	National scale, individual facility locations	2019	Type of care, type of opioid treatment, facility operation (e.g., private, public), etc.	SAMHSA (public)		https://findtreatment.samhsa.gov/locator

Name of Data Source	Type	Geographic Detail	Year	Data Detail	Public or Proprietary?	Other Notes	Link/Path
Administration (SAMHSA)							
TOWN CENTERS							
Main Street America	Location map (state, town/city)	National scale, individual locations of members	Current (2019)	Members are not qualified by size or any other characteristics	Main Street America (proprietary), using Google data		https://www.mainstreet.org/mainstreetamerica/theprograms
Census Incorporated Place [City and Town], TIGER/Line	Web tool	National scale, all census geographies	2010	-	Census Bureau (public)		https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_apps.html
TOURIST DESTINATION							
National Park Service (NPS)		National scale, individual locations	Current (2019)	Type of facility (e.g., park, scenic trail)	Public		https://www.nps.gov/findapark/index.htm
National Trust for Historic Preservation		National scale, individual locations	Current (2019)		Public		https://savingplaces.org/places
State Parks USA	Maps and lists by state			Type of park (state and national forests, grasslands, landmarks, monuments, historic sites, geologic sites, etc.)	State Parks (proprietary)		https://www.stateparks.com/index.html#findPark
America's State Parks	Directory of websites for state parks in all states	National scale, individual parks			Public (states)	Location data / maps not available for all states	https://www.stateparks.org/find-a-park/

Network Data: Characteristics, But No Travel Time

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
Oak Ridge National Labs (ORNL) Transportation Networks	National, limited detail	Highway–Jan 2008 Railroad–Aug 2014 Intermodal network–1999 Intermodal terminals–1998	Highway–Distance and attributes of network that would enable calculation of travel time with functional class and other assumptions Railroad–many attributes of track/ownerships, but travel time is highly operator dependent, not included	– Major Highway – Railroad – Intermodal network which is a composite of Highway, Rail, Waterways, and Intermodal Terminals – Intermodal Terminals	Public	Not an up-to-date source, except perhaps for rail	Weblink
FHWA FAF Network Database (from FAF website)	National, limited detail	2012 network (based on HPMS)[184]	Distance and attributes of network that would enable calculation of travel time with functional class and other assumptions	Highway: state primary and secondary roads, National Highway System (NHS), National Network (NN) and several intermodal connectors	Public	Network used to assign FAF truck flows. Really only covers major roads (not suitable for local access assessments)	Weblink
FHWA FAF Network (from BTS)	National, limited detail	National Highway System Version 2016.09[185]	(Same as above)	(Same as above)	Public	(Same as above)	Weblink
OpenStreetMap	Global, level of coverage varies	Ongoing updates	Includes various information such as coding for whether or not a link is traversable by	Roadway network (down to local streets, although	Free, open source	US network originally imported TIGER	Weblink

[184] https://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf4/netwkdbflow/network/esri/gis_metadata.txt.

[185] https://www.arcgis.com/home/item.html?id=560e1c2711f34aaf904fd8ab1f9333b9.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
			different modes as well as speed limits that can enable calculation of routing/travel time Various available routing systems have protocols for calculating allowed paths and link costs	coverage/accuracy may vary) Also provides information related to pedestrian and bike network		roads from Census in 2007/2008–edits since by community, meaning unlikely to get wholesale updated again[186,187]	
BTS National Transit Map	National, as available	Ongoing updates	Transit systems stops, routes, and schedules that allow fairly direct calculation of travel times (Presumably usable in the same way individual agency GTFS data is, but would require follow up)	Fixed-guideway and fixed-route transit Coverage mostly limited to urban areas (does include smaller systems, e.g., in Lynchburg, VA)[188]	Public	Assembled from GTFS data Data coverage may get better as more agencies are contacted to request data	Weblink Shapefile access
Highway Performance Monitoring System	National, detailed	2017 network (release 10/1/18) Released annually by FHWA	Variables such as: Functional system, facility type, speed limit, AADT (including truck), and indicators of pavement conditions. More detail in documentation[189]	Public roadways, down to minor collectors	Public	Corresponds to federal reporting requirements for system conditions from states	ESRI Geodatabase Shapefile by functional class

186 https://wiki.openstreetmap.org/wiki/TIGER.

187 Possibly useful for understanding coverage and when updates have happened: http://osm-analytics.org/#/show/bbox:-85.89661,38.48819,-76.74500,39.97721/highways/recency.

188 E.g., See: Map of Transit Stops and Buffers https://maps.bts.dot.gov/arcgis/apps/webappviewer/index.html?id=b06d206bcae840d58fb3d0af36e7ee16.

189 https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/page00.cfm.

Network Data: Observed Travel Time

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
National Performance Management Research Data Set (NPMRDS)	National, limited detail	V1 July 2013 (vendor: HERE) V2 April 2017 (vendor: UMD-INRIX-TTI-KMJ-IDAX)	Travel time and speed for passenger vehicles and trucks, available in up to 5-minute intervals, can be averaged up to hourly Updated monthly Also has HPMS variables linked (such as volume) Provides resolution to consider variability in travel time; designed so can be used in national reliability performance measures which are starting to be reported in HPMS data submittals by states	Highway–Generally covers the National Highway System	Available to states and MPOs	Vehicle probe data (real, observed) Available via massive data downloaded, once subscription is set up Very large data sets–ideal for reliability/time of day analysis; would need access to learn more about data coverage in rural areas (but v2 is supposed to have better coverage generally than v1)	Tutorials Presentation with useful information
ESRI StreetMap Premium	National, detailed	Updated on an ongoing basis (2018 currently)	Travel time, including time of day variation based on historical travel times Has separately calculated truck and walk times (can vary walk speed assumptions) Has information on network restrictions (e.g., truck restrictions, roads unsuitable for pedestrians)	Road network, down to local roads[191] Cars, trucks, walking	Proprietary–annual license, on top of ArcGIS and Network Analyst licenses	Like other proprietary data sets: likely expensive but comprehensive single packaged solution For use with ArcGIS software, Network Analyst	Weblink

[191] http://enterprise.arcgis.com/en/streetmap-premium/latest/coverage/product-coverage.htm#ESRI_SECTION1_34295401CE714E72BF49C735076C2049.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
			Can customize whether routing avoids or does not avoid unpaved roads[190] Integrates data from HERE and TomTom				
TomTom MultiNet	USA and Europe coverage, detailed	Ongoing updates	Speed information and supplementary data products available (e.g., ADA Advanced Driving Attributes and historical Speed Profiles SPD)	Road network, down to local roads	Proprietary	Also includes various other spatial elements (Designed to support routing) Shapefiles TomTom has various products/formats to support routing	Weblink Additional Information Little information available publicly; more information in spec provided by EBP (File: multinet_shp_4-8_fs_v1-1-9.pdf)
HERE	Global, coverage varies, transit more limited, details here.	Ongoing updates	Has real-time and historical traffic information Range of functionality including intermodal routing, shortest/fastest route, restrictions, toll calculations, isolines, matrix routing, etc.	Car, Truck, Public Transit, Walking, Bicycle	Proprietary	Using the HERE freemium account you get 250,000 transactions per month	Weblink
INRIX	Global, but level unclear without trial	Ongoing updates	Real-time and historical/predictive traffic information Functionalities include routing and drive time polygons	Cars and Trucks Also has parking data	Proprietary	There is some partnership between HERE and INRIX	Weblink

190 http://pro.arcgis.com/en/pro-app/help/data/streetmap-premium/routing-with-streetmap-premium-in-arcgis-pro.htm.

Non-Network Data: Nodes (Facility Location-Points)

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
BTS Intermodal Freight Facilities	National	Online entry last updated 2018, but data year not entirely clear	N/A Proxy for access provided by intermodal facilities	– Air and Truck – Port and Truck – Rail and Port – Rail and Truck – Truck–Air–Rail – Truck–Port–Air – Truck–Port–Rail – Truck–Port–Rail–Air – Truck and Truck	Public	Part of National Transportation Atlas Database (NTAD).	Weblink
BTS Ports	National	As of October 24, 2018	N/A Proxy for access provided by ports Does provide some potentially relevant info such as commodities handled and water depth	Commercial facilities at United States Coastal, Great Lakes and Inland Ports	Public	Part of National Transportation Atlas Database (NTAD).	Weblink
BTS Airports	National	As of July 13, 2018	N/A Proxy for access provided by airports Includes data on facility type	Public and private aircraft landing facilities, including Airport, Heliport, Seaplane Base, Ultralight, Gliderport, Balloonport	Public	Part of National Transportation Atlas Database (NTAD).[192]	Weblink

Non-Network Data: Coverage

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
Rural Transit Factbook	National (county)	Most recent–2017,	N/A	– Transit supported by 5311 funding	University	Factbook published by	Weblink

[192] Note: Other NTAD available includes Amtrak stations, rail lines, and inland waterways data.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
		using 2015 NTD data, plus other supporting research	Proxy for access provided by transit Data on counties with or without service (5311 or Tribal, does not include urban or other types of services) Also: information on whether 5311 service covers all or part of a county	(FTA Formula Grants for Rural Areas) – Tribal Transit		NDSU Small Rural and Urban Transit Center Maps imply data availability, but data not published	
FCC Fixed Broadband Deployment	National (census block)	June 2017 (latest) Underlying data updates– June and Dec (based on FCC reporting)	# of Providers By Technology: • ADSL • Cable • Fiber • Fixed Wireless • Satellite • Other And Speed: (Mbps download/upload) • ≥ 0.2/0.2 • ≥ 4/1 • ≥ 10/1 • ≥ 25/3 [this is a benchmark] • ≥ 100/10 • ≥ 250/25 • ≥ 1000/100 Good explanation of what speeds mean here.	Residential Fixed Broadband	Public	Data collected by the FCC from carriers on FCC Form 477 Interactive mapping online or data download (have to join data and geographies, not preassembled into shapefiles)	Weblink About Data download

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public /Proprietary	Other Notes	Link/Path
FCC 20Th Mobile Wireless Report, Web Appendix I: Coverage Maps	National (census block)	Maps–2016 Data–December 2017 (Presumably, underlying data updated on the same cycle as above)	Map showing areas with/without service of different types: • Nationwide Mobile Wireless Coverage, Year-End 2016 • 3G or Better Mobile Wireless Network Coverage, Year-End 2016 • Nationwide LTE Coverage, Year-End 2016 • LTE Coverage by Number of Providers, Year-End 2016 (Raw data for custom analysis is more current)	Mobile Wireless	Public	Data collected by the FCC from carriers on FCC Form 477	Interactive online maps Coverage by technology at the census block level (download by provider or by state)

NOTE: There are many routing systems available. The following summarizes some of the most commonly used.

Routing Systems: Use Any Network Data

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
Esri Network Analyst	N/A	N/A	Depends on the network data sets used Relevant functionality: Service Areas Analysis[193]	Depends on the network data sets used	Proprietary–requires Network Analyst license on top of ArcGIS license	Requires a network data set to be useful (although you can also build your own), cf. Esri ArcGIS Online Routing Services for a cloud solution. Available at EBP	Weblink

[193] http://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/service-area.htm.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
			OD cost matrix analysis[194]				
pgRouting	N/A	N/A	Routing engine–costs can be dynamically calculated through SQL–depends on the network data used.	Depends on the network data sets used	Opensource	pgRouting offers routing functionality for PostGIS Querying and analysis done with SQL. PostGIS database is another way of storing and handing spatial data–similar to a shapefile, but designed to handle larger amounts of data	Weblink

Routing Systems: Integrated Network Data and Routing

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
State/Regional Travel Models	State or region specific	Typically updated on LRTP cycles	Travel time and distance May incorporate other variables into generalized cost utility function	Highway at least Regional models often have transit	Public, but in-house	Does not provide a uniform source that covers all of Appalachia	Various
Google Maps	Global	Ongoing	People have built processes for calculating rough isochrones using Google's routing services[195]	Drive, bike, walk Transit where GTFS available	Proprietary, some public access, subject to usage limits	Would require follow up to understand scalability, usage limits, and pricing	Weblink

[194] http://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/od-cost-matrix.htm.

[195] https://github.com/dugwood/isochrone-isodistance-with-google-maps.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
Esri ArcGIS Online (AGOL) Routing Services	High in the US	Ongoing. Historical data is available as well as live and predictive traffic[196].	Travel time and distance, can incorporate barriers, including time of day variation based on historical travel times	Car, Truck, Walking	Proprietary, requires AGOL Organization subscription (available through EBP) Costs are incurred via consumption of AGOL credits[197]	Provides Closest Facility, Service Areas, Origin-Destination Cost Matrix, Location Allocation, Routing, and other tools as plug-and-play functionality in ArcMap or ArcGIS Pro.	Weblink
OpenSourceRoutingMachine	(see OSM details)	(see OSM details)	A function of available data; has an import tool for using OSM data; impedance parameters defined by configuration Offers classic routing, but not isochrone functionality	(see OSM details)	Opensource	C++ based routing engine designed for using OSM data and handling very large networks	Project weblink Github
Open Route Service	(see OSM details)	(see OSM details)	Built on OSM data Offers API services for: Isochrones Time-Distance Matrices Identification of Points of Interest based on OSM node data *Also offers a QGIS plugin*	Road, pedestrian, and bicycle Potentially additional specifications for cargo/transit, depending on data	Free but limited APIs	Would require follow up to understand potential for batch processing Interactive online tool also	Weblink Preview isochrones here

[196] https://doc.arcgis.com/en/arcgis-online/reference/network-coverage.htm.

[197] https://www.esri.com/en-us/arcgis/products/arcgis-online/pricing/credits.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
			Requires selection of impedance parameters			totals population within isochrones automatically	
OSM Tools	(see OSM details)	(see OSM details)	Routing, isochrones, and matrix calculations based on OSM	(see OSM details)	Opensource	QGIS plugin from Open Route Service, offering most of their functionality in the QGIS environment	Weblink
Hqgis	N/A	N/A	Travel time, distance, "balanced" Traffic, routing, isochrone, geocoding based on the HERE API[198] from within QGIS	Car, bicycle, walking, maybe more	Open source tool, proprietary API. Using the HERE freemium account you get 250,000 transactions per month	Designed to work in QGIS 3.4 or above	Weblink Github
TomTom Routing Services	(See TomTom network details)	(See TomTom network details)	(See TomTom network details)	(See TomTom network details)	Proprietary		Weblink

[198] https://developer.here.com/

Network Data Import Tools

There are many technical solutions to enable interoperability between network data sets and routing systems. Below is a selection identified based on a review of commonly used tools.

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
Esri ArcGIS Editor for OpenStreetMap	N/A	N/A	(A function of available OSM data; impedance defined by configuration files)	(A function of available OSM data)	Free, open source	Includes Create OSM Network Dataset tool[199] for creating a network dataset from OpenStreetMap data.	Weblink Github
Geofabrik routing enabled OSM shapefiles for use in a routing tool	N/A	N/A	A function of available OSM data, impedance defined by the configuration of the routing engine you plan to use this data with	car, bicycle, walking	Proprietary Free (non-routable) OSM downloads in typical GIS formats are available as well.	Cost: USD 550–850	Weblink
osm2pgrouting	N/A	N/A	(A function of available OSM data; impedance parameters defined by configuration files)	(A function of available OSM data)	Opensource	Imports OSM data into pgRouting	Weblink
ESRI Add GTFS to a Network Dataset	N/A	N/A	GTFS data defines routes, stops, and transit schedules (assuming it is complete)	Public transportation (if GTFS data available)	Tool is free, but to be useful need ArcMap and Network Analyst licenses as well as street data	"Use Add GTFS to a Network Dataset to incorporate transit data into a network dataset so you can perform schedule-aware analyses using the Network Analyst tools in ArcMap."	Weblink

[199] https://github.com/Esri/arcgis-osm-editor/wiki/Create-a-network-dataset-from-osm-data

Select Accessibility Databases

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
Access Across America	National, at the census block level Public reports focus on top 50 metros	Transit 2017 Auto 2017 Walking 2014	Transit 2017:[200] • GTFS data + OpenStreetMap for walking • Cumulative access to jobs w/in 5, 10, 15, ..., 60 minutes (jobs from LEHD-LODES) • Travel times averaged over the period 7-9am, to reflect influence of service frequency (departures at 1-minute intervals) • Calculations with OpenTrip Planner (including custom extensions) Auto 2017:[201] • TomTom's MultiNet and Speed Profile datasets (observed speeds, 5-minute resolution available) • Cumulative access to jobs w/in 5, 10, 15, ..., 60 minutes (jobs from LEHD-LODES) • Travel time calculated for one-hour intervals across the day (study averages across all hours and also compares 8am access to maximum access in a 24-hr. period to see the influence of congestion)	Transit Auto Walking	Detailed data available to study fund participants for their jurisdiction	Project of UMN Pooled-fund study Focuses on job access, only Appalachian state participants: TN, VA Also provides useful examples of aggregating and ranking areas (uses decay function for aggregation in the ranking process) Some discussion among participants of limitations of GTFS data in rural areas	Weblink Pooled fund study website

200 http://cts.umn.edu/Publications/ResearchReports/pdfdownload.pl?id=2920 and http://ao.umn.edu/research/america/transit/2017/index.html

201 http://cts.umn.edu/Publications/ResearchReports/pdfdownload.pl?id=2948 and http://ao.umn.edu/research/america/auto/2017/index.html

Name of Data Source	Geographic Detail	Year	Impedance details	Mode	Public or Proprietary?	Other Notes	Link/Path
			• Calculations with OpenTrip Planner (including custom extensions) Walking 2014:[202] • OSM network • Cumulative access to jobs w/in 10, 10, 20, …, 60 minutes (jobs from LEHD-LODES • Calculations with OpenTrip Planner				
All Transit	National, for 371 metros (CBSAs) over 100,000 pop, at the census block group level. Smaller regions with available GTFS data are also included.	Unclear	Jobs within 30-minute transit commute, based on GTFS (not clear how time of day variation handled) 102 agencies shared GTFS For 273 agencies, CNT constructed data Jobs data from LEHD LODES Visually, does have coverage above what is currently in the BTS National Transit Map	Transit–scheduled bus, rail, and ferry service	Proprietary	Also used in CNT's Housing + Transportation Affordability Index	Weblink Methodology

[202] http://access.umn.edu/research/america/walking/2014/documents/CTS15-04.pdf