Freight Performance Measures: Measuring Freight Accessibility

White Paper

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SUMMARY

This white paper presents research and guidance for the measurement and analysis of freight accessibility. This topic is important because it reflects the ability of industries in the economy to move goods to their customers and to access material inputs from suppliers. Without such access, regional, state, and international trade is constrained and regions face challenges in attracting and sustaining business activity. Freight accessibility concerns arise when the capacity, cost or performance of existing freight access corridors is threatened, or when economic shifts dictate the need to access new destinations or freight services. Some areas have long struggled with access limitations from isolation, while others may be facing new constraints related to congestion or other growth pressures.

Because the success of the U.S. economy depends on a well-performing freight transportation system, measurement approaches are needed to assess and track this performance in terms of the system's ability to provide access to customer and supplier markets. Freight accessibility is fundamentally about measuring the breadth or size of accessible markets. It extends beyond considerations of how well the system can move goods from point A to point B along the existing network. Instead, freight accessibility measurement works to quantify how well the system connects business with desired opportunities for economic engagement.

While local communities, regional/state agencies, and individual businesses have long promoted improvements in freight system accessibility, MAP-21 legislation has helped to highlight the critical role that freight plays in our nation's economic vitality. Addressing increasing interest in and need for comprehensive and consistent guidance regarding freight accessibility measurement, this research was developed for the Federal Highway Administration (FHWA) Office of Freight Management and Operations (HOFM) and the American Association of State Highway and Transportation Officials (AASHTO). The research was developed to grow and support the state of practice in measuring freight accessibility, while acknowledging the diversity of access issues across the county, as well as different levels of data and analytical resource availability within agencies.

The white paper is organized as follows: Chapters 1 and 2 provide an overview of freight accessibility issues and concepts in the literature as well as available measurement approaches. Chapter 3 presents a core set of recommendations for a step-by-step process that can be used to evaluate freight accessibility. The approach is intentionally flexible and can be applied to a variety of development settings, scales of analysis, and sources of accessibility constraints. Chapter 4 uses four cases to illustrate the measurement approach using on-the-ground experience and data from different areas across the county. Chapter 5 presents overall findings of the research.

1 UNDERSTANDING FREIGHT ACCESSIBILITY

This chapter explains the motivation for the research project, defines freight accessibility and its relationship to economic competitiveness, and summarizes the state of freight accessibility analysis methods within research and practice.

1.1 Motivation and Overview

This project is motivated by the growing interest in understanding freight system performance and its relationship to economic vitality. Businesses of all varieties depend on access provided by the freight transportation system—to access customer markets as well as to obtain material inputs to production. Any failure to provide adequate access can reduce business competitiveness and thus economically disadvantage a community or region.

The recognized linkage between freight accessibility and the viability of freight-reliant industries creates a need for ways to measure and evaluate accessibility issues, with the end goal of: (1) enabling assessments of local, regional, and national disparities in accessibility; and (2) providing decision-support for projects, programs, and policies aimed at improving freight accessibility.

To address these goals, this research effort first defined the relevant dimensions of freight accessibility, and subsequently developed measurement and analysis approaches that can capture these dimensions across a variety of geographic scales. The approach described in this report is designed to address different underlying causal factors behind freight accessibility issues (e.g. congestion, gaps in the network, modal availability) and to enable comparative analyses across space and time. The approach is flexible in that it acknowledges differences in data availability, modeling capacities, and requirements for detail versus scalability in selected analyses approaches.

Freight Accessibility and Economic Competitiveness

A significant body of work exists on the linkage between transportation and economic productivity, including the recently published NCHRP Report 786 Assessing Productivity Impacts of Transportation Investments.[1] Figure 1 illustrates the relationship between the passenger and freight transportation system and economic activity along the supply chain.

Fundamentally, access is the ability to reach places in order to engage in a set of desired activities—activities that affect economic activity and the flow of money in the economy.

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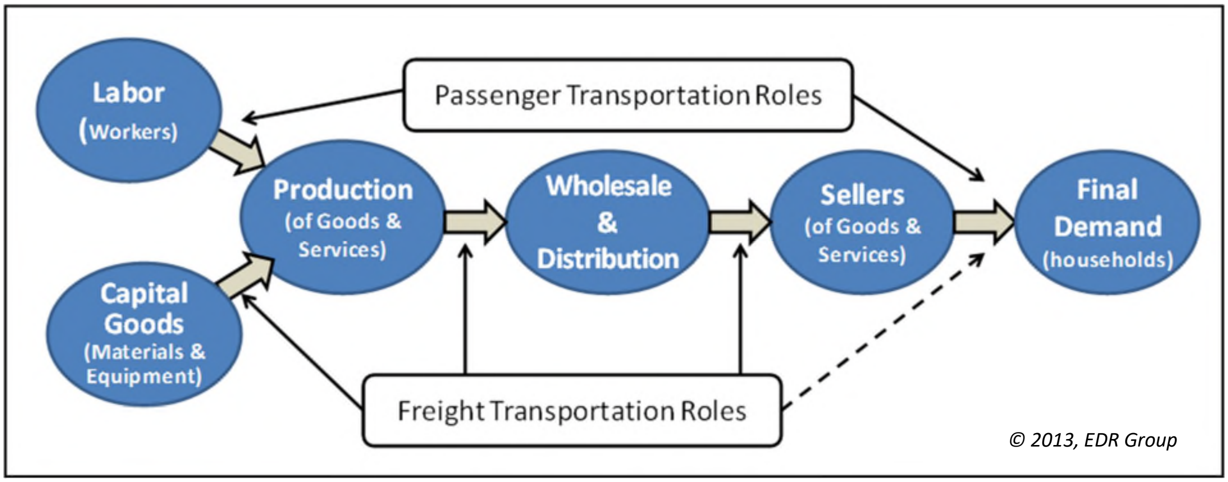
[1] Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_786.pdf

Unless activities are co-located, transportation is a necessary intermediate good to provide that access. In the *passenger* realm, transportation infrastructure enables access to work, shopping, recreation, health care and education. In the *freight* realm, transportation infrastructure access enables businesses to (1) move input supplies and materials to producers, and (2) move products to customers, with varying levels of efficiency.

Figure 1 Transportation and the Economy



Source: NCHRP Report 786 Assessing Productivity Impacts of Transportation Investments.

Much of the existing research on market access is concentrated on issues related to labor market access and resulting improvements in matching between business needs and available employee skills. Nevertheless, similar effects have been identified for businesses in the freight transportation realm related to access to supplier markets for raw materials and intermediate goods, as well as access to customers. Tightening the connections between buyers and suppliers and between companies and their customers leads to productivity improvements.[2] Reduced travel times or congestion-related delays can expand the customer delivery market that can be effectively served with one-day deliveries from a given facility. A larger customer market will enable certain business activity to become profitable, in a way that it would not have been with a smaller market. Improved access can also support investment in technology or production processes that will make businesses more productive, and can produce better matching between customers and demand for specialized goods.[3] Transportation performance improvements can additionally expand access to same-day parts or material suppliers, thus potentially increasing availability and reducing costs of obtaining specialized inputs.

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[2] Alstadt et al. The Relationship of Transportation Access and Connectivity to Local Economic Outcomes: A Statistical Analysis. Transportation Research Record, 2012.

[3] NCHRP Report 786 Assessing Productivity Impacts of Transportation Investments.

MAP-21 Legislation and Performance Management

In MAP-21, for the first time in national surface transportation law, freight transportation receives prominent attention. MAP-21 includes a significant number of freight provisions that aim to focus the Federal-aid highway program on several national goals including one for freight movement and economic vitality. This goal is to "improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development." A list of the MAP-21 freight provisions are summarized in Table 1.

A key theme of this national goal is accessibility, the ability to reach markets and the ability of goods to move more efficiently and freely to their destinations. To reach this goal, MAP-21 requires states and MPOs to focus on freight performance measurement and planning and calls for the Secretary of USDOT to develop data and analytical tools to support the development and evaluation of freight projects. It is within this context that the present research into freight accessibility measurement is being conducted. As specified in the proposal request for this project:

> In the spectrum of freight performance management, accessibility for freight transportation has been identified as a core measure. FHWA believes post-MAP 21 there will be a strong push to develop measures for accessibility. Research is needed to better define the concept and approach to measurement.[4]

Table 1 MAP-21 freight provisions

Freight provision	Description
National Freight Policy	The U.S. DOT will establish and maintain a policy to improve the condition and performance of the national freight network to support economic growth and competitiveness.
National Freight Network, Primary Freight Network, and Critical Rural Freight Corridors	The DOT is required to establish a National Freight Network to assist states in strategically directing resources toward improved movement of freight on highways. The network will include a primary freight network (PFN), any portions of the Interstate not part of PFN, and a set of critical rural freight corridors. The PFN will be designated by DOT. States will designate critical rural freight corridors.
National Freight Strategic Plan	The U.S. DOT is required to develop and update every five years a plan for accomplishing a number of freight related objectives, including assessing the condition and performance of the national freight network; identifying bottlenecks, gateways and corridors; assessing barriers to improved performance; and providing a process for addressing multistate projects and strategies to improve freight intermodal connectivity.
Freight Data, Planning, and Reporting	U.S. DOT is directed to develop data and analytical tools to support developing and evaluating freight projects.
Freight Conditions and Performance Report	U.S. DOT is tasked with producing a biennial report on freight transportation conditions and performance.

[4] FHWA/AASHTO Approaches to Measuring Accessibility on the National Highway System (NHS) Task Order Proposal Request.

Prioritization of Projects to Improve Freight Movement	A higher federal matching share can be obtained for projects that demonstrate that they produce a significant improvement in freight movement relative to the national performance measures and targets set by the states.
State Freight Plans	States are encouraged to develop freight plans which are required in order to qualify a project for the higher federal matching share described above.
State Freight Advisory Committees	States are encouraged to establish State Freight Advisory Committees to advise on state freight policies, plans and projects.
Projects of National and Regional Significance (PNRS)	The discretionary PRNS program targeted at large scale projects that provide significant regional and/or national benefits continues under MAP-21.
Metropolitan and Statewide Planning	General support is expressed in MAP-21 for planning to increase accessibility, mobility, and connectivity for freight by all modes and for involving the freight industry in the MPO and state planning processes.
Performance Measures	U.S. DOT must establish freight performance measures for states to assess freight movement on the Interstate System and states must set targets, incorporate them in the planning process, and report on progress in relation to these targets.

Source: FHWA. Significant Freight Provisions. MAP-21 Fact Sheets.[5]

The framework established by MAP-21 highlights the importance of freight performance to the country's economy as a whole and suggests that performance-based planning be used to support improvements to the freight system. Defining and using accessibility measures will improve understanding of how well the freight system is performing. This includes performance both on the highway system and from a broader multi-modal and intermodal perspective.

At the federal level, freight access measures may be used to generally assess the national freight system condition and performance and to track changes over time in support of National Freight Policy, the National Freight Strategic Plan, and the Freight Conditions and Performance Report (see Table 1). They may also be used to support the identification of national or regionally significant project needs to aid in investment decision-making.

While MAP-21 creates requirements for certain performance reporting on the part of States DOTs, this project is aimed at growing and supporting the *overall* state of practice in measuring freight accessibility, both for federal reporting and tracking, *and* for local, regional, and state uses. Freight accessibility measures can be used to support a variety of freight planning needs at the State and local level, including:

- Strategic planning;
- Target setting and progress tracking;
- Prioritization and individual project assessments;
- Demonstration of a project's benefits, in support of funding applications; and

[5] http://www.fhwa.dot.gov/map21/factsheets/freight.cfm Accessed 12 May 2014.

- Evaluations in support of economic development strategy development.

A core understanding of access will provide the basis for both general measures and the flexibility needed for the application of the core concept in different situations and for different purposes.

1.2 Freight Accessibility in Research and Practice

Before diving into the various metrics available for freight accessibility analysis, it is necessary to first establish the sources of freight accessibility issues faced by communities and businesses, the dimensions important to freight accessibility analysis, and the various planning contexts in which States and MPOs are likely to employ measurement approaches. The material presented in this section draws on information collected during a review of existing research literature and agency practice.

Defining Accessibility

While freight access is a widely sought after goal and extensively considered constraint within the world of transportation planning, accessibility as a measurable concept has been far more completely defined and debated within the passenger transport realm than as it applies to freight.

In 1959 Hansen coined a now much-cited definition of accessibility as “the *potential* of opportunities for interaction.”[6] Other definitions include “the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction”[7] and “the benefits households and firms in an area enjoy from the existence and use of the transport infrastructure relevant for their area.”[8] Alstadt and Weisbrod (2012) called attention to the multi-faceted nature of accessibility as a composite phenomenon that includes a number of different dimensions—such as labor market, customer market and intermodal connectivity access—and that has economic productivity impacts that vary by industry.[9] Similarly, a National Cooperative Highway Research Program (NCHRP) report titled *A Guidebook for Performance-Based Transportation Planning* states that “measures of

[6] Hansen, Walter G. “How Accessibility Shapes Land Use.” Journal of the American Institute of Planners, Vol. 25, No. 2, 73-76 (1959).
[7] Dalvi, M. Q. and K.M. Martin. “The Measurement of Accessibility: Some Preliminary Results.” Transportation, vol. 5, No. 1, 17-42 (1976).
[8] Wegener, et al. “Criteria for the Spatial Differentiation of the EU Territory: Geographical Position.” Study Programme on European Spatial Planning. 2001.
[9] Alstadt, Brian and Glen Weisbrod (2012). The Relationship of Transportation Access and Connectivity to Local Economic Outcomes: A Statistical Analysis. Transportation Research Record: Journal of the Transportation Research Board, Issue Number 2297, 154-162.

accessibility should reflect the ability of people and goods to access services, use different modes, and reach different destinations."[10]

This report builds on an existing accessibility knowledge-base while also highlighting issues particular to freight.

Causes of Freight Accessibility Constraints

The following factors are often cited by transportation and economic development professionals as sources of access-related business growth and development constraints:

***Geometric constraints*.** The physical design of a roadway can constrain the ability of larger trucks to pass. Relevant dimensions include road width, clearance, turning radius, weight limits, and the existence of passing lanes or shoulders. Similarly, some rail routes may lack the vertical clearance for double-stacked container movements.

***Volume-to-capacity constraints*.** Particularly in the vicinity of urban areas and major freight terminals, mobility on the freight network can be constrained by congestion. Delay and unreliability associated with congestion reduce the number of activities that can be reliability reached with a given time and cost and thus reduce the level of access provided by the transportation system.

***Service provision and scheduling constraints*.** Unlike highway infrastructure, which is almost always available[11] and permits all connections physically provided for by the infrastructure, other modes of freight transportation only operate service on a certain schedule with a given frequency, number of destinations served, and available capacity. These service variables all determine the level of accessibility provided by intermodal terminals. In urban areas, local roads may also have delivery window regulations that impose scheduling constraints.

***Circuity, network coverage, and remoteness*.** Apart from the more localized geometric constraints mentioned above, the spatial pattern of transportation network coverage and freight activities can together enable or constrain access. Remote areas, for example, are often poorly served by freight operators, because of the low demand in those areas. Some areas may also have limited roadway network coverage because of high construction costs (associated with geological features like mountains or rivers) coupled with low demand (less dense settlement patterns) and other spatial constraints dictated by environmental regulations or land use patterns. Nevertheless, some industries may not have the freedom to relocate to more accessible areas because of a need to be near inputs such as a hydropower plant or farm land.

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[10] Cambridge Systematics. NCHRP Report 446: A Guidebook for Performance-Based Transportation Planning, 2000. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_446.pdf Accessed 3 February 2014.

[11] With exceptions including construction closures, infrastructure failures, or weather/event-related closures.

Given the various sources of access constraints described above, accessibility can be described as the product of the interaction between spatial or land use patterns (i.e., the location of users of the freight system) and transportation networks (the available infrastructure and service for moving goods between origins and destinations). As will become clear in this report, different types of metrics can be used in concert to a) describe the underlying causes of accessibility issues and b) quantify the extent or severity of reductions in accessible market size.

Important Dimensions of Freight Accessibility

Consideration of freight accessibility must address the inherent multi-dimensionality of supply chains and access requirements of different businesses. Based on existing literature, the following dimensions have been identified as being critical to understanding freight accessibility:

***Multi- and inter-modality*.** A key characteristic of the freight transportation system is the importance and connections between multiple modes. Just the domestic portion of a given product's supply chain might involve: unloading from a ship at a seaport, drayage by truck to an intermodal facility, transshipment to double-stack rail, unloading onto a tractor trailer for delivery to a distribution center, and ultimate delivery to a retail establishment by a single-unit truck. Road-to-rail, road-to-air, and road-to-marine transfers are key components of a functioning freight system. This presents a challenge for the specification and use of accessibility metrics. Development of integrated network data for multiple modes at a national scale is challenging and likely out-of-scope for many types of analyses. Nevertheless, as freight modeling and other spatial data are developed more fully, there will be new opportunities to assess freight transportation from a truly multimodal perspective (taking into account different cost structure across modes, as well as transfer costs between modes). Transit accessibility approaches may offer some guidance, as another related field addressing a high degree of inter-modality (i.e. bus-to-rail, walk-to-bus, etc.).

***The importance of nodes*.** Because of the importance of intermodal connections, and the challenges associated with representing them adequately within a network data set, much of the literature chooses to focus on measuring access to nodes or intermodal terminals. These terminals serve as entry points ("gateways") to broader freight transportation networks with desirable service qualities (speed, cost, level of connectivity, etc.). For example, measures might focus on access to the interstate highway system or to seaports as a means of accessing a larger-scale distribution system. Nevertheless there remains the challenge of accounting for the service level differences between nodes: no matter how accessible it is by road, an airport, seaport, or rail terminal with no appropriately timed connections to the desired destination or without available capacity will be of no benefit to a shipper. One approach to account for these constraints is to weight each node by a variable (or multiple variables) that proxies for the access provided at the node, such as:

number of flights per day, service frequency, or annual volume of freight moved through the terminal.

Industry-specific needs and multiple access types. The freight transportation system is characterized by a wide variety of users and by significant variety in access needs. Accessibility requirements depend on business type and location, as well as on the location of a business's buyers and suppliers. Some businesses and industries have global-scale supply chains, while others may have more localized needs for access. In addition, the carrying requirements vary by type of freight according to characteristics such as value-to-weight ratios, fragility, and timeliness requirements. To reflect this, metrics are often differentiated to measure access to different types of activities. For example: measuring access to customer markets for same-day delivery versus measuring access to intermodal facilities for national or international distribution. When addressing the needs of a particular freight cluster or freight generator, more targeted analysis may be appropriate to understand the needs of a particular industry.

Scale differentiation. Freight access issues and their corresponding measurement requirements span a variety of scales. Sometimes access issues can be detected at a regional level, such as when congestion on a major arterial affects region-wide access or when an entire region suffers from low levels of scheduled rail service at the region's only terminal. In other cases access issues are highly localized, as when at outdated interchange does not meet current operational standards and therefore creates a bottleneck. In addition, metrics themselves may be strategically targeted to measure access to networks that have different levels of geographic reach – for example the difference between access to a port with global liner service to Asia and access to a short-line railroad. Measurement approaches may also be designed to enable easily replicable application across many geographies—or may be highly targeted to the needs and issues of a particular location.

Bearing in mind the above dimensions, the next section of this report reviews the inclusion of freight accessibility issues and measures in public agency planning and evaluation practices.

Freight Accessibility in State and MPO Practice

Freight accessibility measures can be used in a multiple ways to support decision-making within a performance-based transportation program. U.S. DOT, States, and MPOs each have their own needs that can be supported by freight accessibility measures. In fact, a review of the current state of practice shows that freight accessibility is already commonly acknowledged as a key category of performance considered by States and MPOs—but that the ways in which freight accessibility is accounted for include a range of qualitative and quantitative approaches. The goal of this project is to provide support for more rigorous and systematic evaluations of freight access, including the use of well-defined quantitative metrics.

The following sections address the use of freight accessibility measures at different scales of government, and within different stages of the planning process. The discussion draws on observations from the current state of practice to help define a framework for multi-scalar assessments of freight accessibility.

Long Range Planning

Within state and MPO long-range planning, freight accessibility and related concepts are included in the setting of policy objectives and are used as a lens through which to track progress. One common approach is to apply performance measures in relation to specific freight activity locations or subsets of the transportation network that are identified as being significant to freight accessibility. The Minnesota Department of Transportation, for example, established a framework in which performance measures (cost, travel time, delay, travel speed, congestion) are applied specifically to infrastructure that serves important markets or key freight generators. Constraints on access are also commonly detailed or used as criteria for selection of major projects. In most cases, agencies do not explicitly measure accessibility.

Table 14 in the Appendix summarizes a range of representative examples of freight accessibility's inclusion in long-range planning, organized into three main topic areas: (1) goal setting and priority definition, (2) tracking of freight accessibility issues, and (3) enumeration and evaluation of specific freight access issues.

Prioritization

Within the prioritization process, there has been increasing recognition that traditional engineering measures of travel time or cost savings and safety enhancements do not provide a complete picture of potential benefits from proposed projects. Acknowledging the importance of transportation in supporting economic development, agencies are choosing to include factors related to passenger and freight accessibility, as well as intermodal connectivity, within their evaluation frameworks. In most cases, these factors are qualitative scorings, rather than quantitative metrics. The intent of these factors is to be applied in a consistent and replicable manner across a broad range of projects.

Table 15 in the Appendix presents example criteria from published project rating systems that in some manner address the issue of freight accessibility.

Project Evaluation

Freight accessibility is addressed in the most specific terms within the evaluation and justification of single projects. At this scale, planners and engineers are most concerned with the performance of specific assets within the transportation system, relative to the requirements (current or planned) of an identified freight generating location. Unlike the more universal approaches needed for planning and prioritization, individual project evaluations can be more detail-oriented and context specific.

At the project or site-specific level of analysis, land-use and its relationship to freight accessibility also becomes an important planning consideration. Accessibility concerns are often triggered by changes that threaten an existing base of economic activity, including (1) factors that threaten to negatively affect the capacity, cost or performance of existing freight access corridors, and (2) shifts in the economy that require new types of freight access to maintain economic viability.

Encroachment by incompatible land uses and changing growth patterns in the vicinity of freight-generating activities are a common sources of freight access constraints—whether because of increased traffic in an area, or because of pushback from a community (including regulation) that limits the ability of a freight generator to expand operations. To address these types of issues, the FHWA has released a Freight and Land Use Handbook to help agencies “coordinate freight transportation and land use planning activities to ensure that transportation facilities are compatible with adjacent land uses, or that land use decisions are consistent with freight mobility and operational needs."[12] Land use planning, including anticipation of future development trends and their implications for localized access, is an important part of the freight planning process. Nevertheless, land use planning considerations do not directly affect accessibility measurement approaches. As appropriate, land use constraints will be highlighted in the Chapter 4 case studies.

[12] FHWA Freight and Land Use Handbook, 2012. Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop12006/fhwahop12006.pdf Accessed 14 May 2014.

2 FREIGHT ACCESSIBILITY MEASUREMENT APPROACHES

Chapter 1 provided an overview of freight accessibility as a concept, its relationship to economic competitiveness, and how freight accessibility measures fit into the planning process. This chapter now transitions to a more structured and detailed classification of available accessibility measurement approaches.

Two widely adopted types of freight accessibility metrics in research and practice are *infrastructure-based measures*, which focus on the mobility associated with transportation infrastructure or services, and *area-based measures*, which aim to quantify the accessibility of a given location.[13]

These two sets of measures are different in terms of their measurement approach, but interrelated in terms of their capacity to identify and assess freight accessibility problems or constraints. Infrastructure-based measures are best suited to identifying the transportation performance factors that may constitute the sources of accessibility constraints. Area-based measures quantify the accessibility of a given location or user group.

In addition to measures that fit into the more academic categorization of infrastructure- or area-based measures, there is yet another class of measures that can be classified as network coverage or completeness measures. Rather than measuring performance on specific links or at specific nodes within the transportation network, these additional measures describe properties of the network itself and are addressed along with infrastructure-based measures in Section 2.1.

2.1 Infrastructure-Based and Network Measures

Infrastructure-based measures focus on capturing the level of performance on transportation infrastructure that serves a given place. Infrastructure-based measures are applied at the link- or corridor-level, and in some cases to particular nodes within the system. They measure factors that affect accessibility and thus overlap considerably with other (non-accessibility) categories of transportation and freight performance measures. Common infrastructure-based measures used to characterize factors affecting freight access are shown in Table 2, along with a description of the infrastructure elements to which they are typically applied, and the other performance areas to which they also relate.

[13] Geurs and van Wee, 2004.

Table 2 Infrastructure-based Measures

Infrastructure-based Measure	Infrastructure Application
Travel time (or speed)	on a link, corridor, or between a selected origin-destination pair; a measure of general ***mobility***
Waiting or transfer time	at border crossings, ports, intermodal facilities, etc.; a specific measure targeted at ***bottlenecks***
Volume-to-capacity ratio	for a specific facility, mapped across a network, or measuring the number of miles that exceed a certain threshold; a measure of ***congestion***
Travel time index (TTI)	the ratio of a selected upper bound percentile of travel time to the median travel times on a selected path (link, corridor, or between a selected origin-destination pair); a measure of ***unreliability***
Fluidity indicator	As defined by Transport Canada, the fluidity indicator is targeted at measuring end-to-end supply chain performance, e.g. "total transit time of inbound containers from overseas markets to strategic North American inland destinations via various Canadian gateways"[14]; a measure of ***fluidity***

Infrastructure-based measures can be applied to any set of selected links and nodes. In some cases, the measures are applied to specific corridors, links, or nodes that have been identified by planners and freight stakeholders as being particularly important to freight movements. In this case, the measures incorporate an implied focus on origins and destinations. For example, the AASHTO Standing Committee on Performance Measurement suggests that targets for their proposed *Annual Hours of Truck Delay (AHTD)* measure and their *Truck Reliability Index (RI_{80})* could be established "for truck trips on multi-state corridors between major city pairs, and at major international border crossings."[15] Similarly, Virginia experimented with a distance-weighted TTI metric for all road links within a 10-mile buffer of key freight nodes.[16] Infrastructure-based measures, however, do not directly incorporate measures of the activities that attract freight movements—i.e. the opportunities afforded by freight accessibility. Area-based measures, discussed in the following section, offer this crucial "access to what" perspective.

Network coverage and completeness measures, like infrastructure-measures, capture characteristics of the transportation system, without directly measuring land-use and activity distributions in geographic space. They measures network properties related to the coverage, directness, and connectivity of the transportation system. In practice, these measures are applied to a particular geography and are used to compare network characteristics across different target areas. Table 3 presents a set of measures that could

[14] Transport Canada. Gateways and Corridors: Fluidity Indicator. https://www.tc.gc.ca/eng/policy/anre-menu-3023.htm Accessed 8 May 2014.

[15] AASHTO Standing Committee on Performance Management: Task Force on Performance Measure Development, Coordination and Reporting. SCOPM Task Force Findings on MAP-21 Performance Measure Target-Setting. March 2013. Available at: http://scopm.transportation.org/Documents/SCOPM%20Task%20Force%20Findings%20on%20Performance%20Measure%20Target-Setting%20FINAL%20v2%20%283-25-2013%29.pdf Accessed 12 May 2014.

[16] Virginia Office of Intermodal Planning and Investment. Task 1 Technical Memorandum Measuring Accessibility of Intermodal Centers. http://www.vtrans.org/resources/reports/Task_1_Technical_Memo_8_14_12.pdf

be applied to a local or regional geography around a point of interest (e.g. a freight generator such as a port or industry cluster). This set of measures was developed and tested by Virginia as part of the agency's recent pilot on accessibility measurement. The local measures capture last-mile issues, while the regional measures are aimed at issues of network connectivity at the scale of a same-day truck delivery market.

Table 3 Network Coverage and Completeness Measures[17]

Local Measures	Regional Measures
(e.g. within a 1 mile radius of a key node)	(e.g. within a 3 hour/100 mile radius of a key node)
- Number of intersections (measures network connectivity) - Roadway centerline miles - Network directness index (a measure based on the ratio between straight-line and network distances)	- Truck network centerline miles[18] - Double-stack rail miles - Rail track centerline miles - Rail track miles of siding (represents increased operational efficiency from passing) - Number of intermodal facilities

2.2 Area-Based Measures

Area-based measures capture accessibility of a certain location or area, relative to a set of other spatially distributed activities. Within the academic literature, area-based measures are more broadly accepted (than infrastructure-base measures) as measures that capture the full meaning of accessibility—meaning access *for whom* and *to what*. They measure accessibility itself, rather than measuring performance or composition of the transportation network that enables or constrains freight access. Nevertheless, infrastructure-based and network measures can also capture elements of accessibility if they are applied to key origin-destination pairs or to key freight generators.

There are three key dimensions of an area-based measure that together define the details of any particular measurement approach:

(1) The ***user group*** (defining the perspective of the measure),

(2) The ***attractions or destination*** to which access is being considered, and

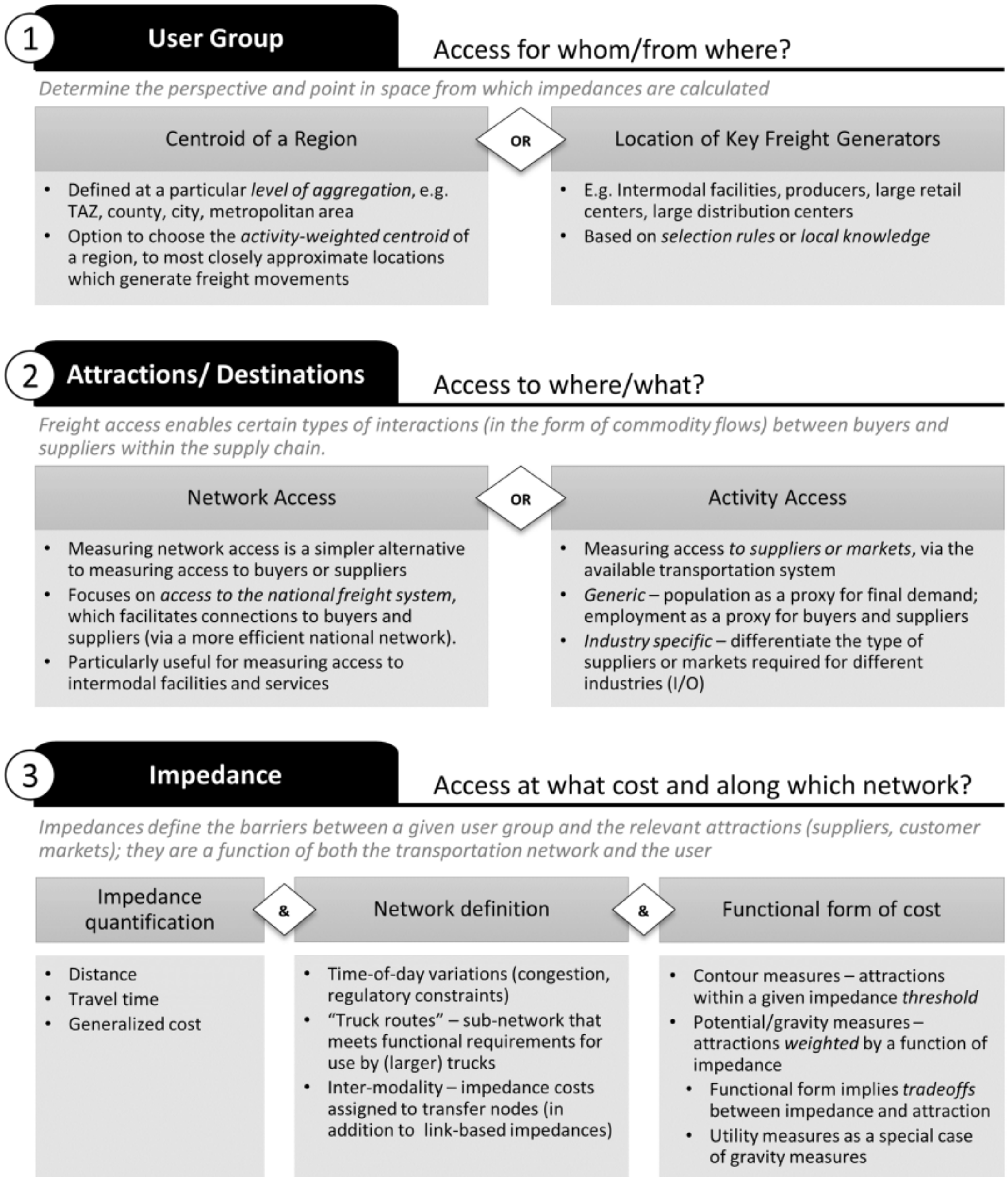
(3) The ***impedances*** that limit access between the former two.

Figure 2 presents a taxonomy of these three dimensions, with various options presented under each of the three headers.

[17] Based on measures developed as part of Virginia Office of Intermodal Planning and Investment pilot project. For more information, refer to the Task 1 Technical Memorandum – Accessibility of Intermodal Centers, retrievable from: http://www.vtrans.org/reports_and_studies.asp#access

[18] Virginia defined the truck network as the national network allowing large trucks, as per the Surface Transportation Assistance Act of 1982 (STAA).

Figure 2 A Taxonomy of the Most Common Area-Based Measurement Approaches



User Group

The first choice within this taxonomy is that of the user group. The analyst must select the point in space from which impedances are calculated. If the process is to be applied in an automated or uniform fashion across an entire region, the most common choice is the centroid (weighted or unweighted) of a particular zone—a transportation analysis zone (TAZ) from a travel demand model, for example. An alternate approach is to focus specifically on generators of freight activity. This approach does not attempt to develop a measure of access for every zone in a region. Rather, it selects a set of key freight generators and thus focuses the analysis. This approach already shows up in state practice. For example, the Minnesota Statewide Freight Plan completed in 2005 reports on measurement of the *percent of major generators with appropriate roadway access to interregional corridors (IRCs) and major highways*.[19] The focus on specific generators is akin to the focus of certain infrastructure-based measurement approaches on identified subsets of the transportation system that are particularly important for freight movements.

Attractions or Destinations

The second choice faced by an analyst is the selection of attractions or destinations to which access is measured. The "access to what" component of analysis is central to the idea of accessibility. Accessibility is about providing businesses with access, up and down the supply chain, to (a) their required material inputs which must be transported from the location of relevant suppliers, and (b) markets for their products, accessed by means of transport to the location of relevant buyers. Given the disaggregate and varied nature of industry requirements, there are a variety of approaches available for measuring relevant activities or opportunities. Each approach creates a proxy variable at some level of abstraction. Accessibility metrics are necessarily aggregate and no area-based measure will by itself fully capture the level of access an individual business has to its potential buyers and suppliers. Nevertheless, there are opportunities for industry-specific approaches.

A *network access* approach uses access to the national freight system (defined as access to a highway interchange, rail terminal, or a port) as a proxy for the buyer and supplier markets that are (more) efficiently accessible via the higher-speed and lower-cost "backbone" of the transportation system. It focuses on the impedances of so-called "last mile" connections and, in some cases, the importance of intermodal services. If measuring access to an intermodal facility, the analyst may choose to incorporate an activity variable that captures the level of service provide by the other mode (e.g. number of flights or trains per day, # of destinations reachable, etc.). Adding this weight would result in a functional form more similar to that of the activity access metrics discussed next (see Equation 1).

Equation 1 Generic form of an area based measure

$$A_i = \sum_i g(W_j) f(c_{ij})$$

Where A_i is the accessibility of zone i, $g(W_j)$ is the activity function for zone j, and $f(c_{ij})$ is the impedance function that captures the costs incurred in moving from zone i to zone j.

[19] Minnesota DOT. Minnesota Statewide Freight Plan, 2005. Available at: http://www.dot.state.mn.us/ofrw/PDF/MN_SFP_Final_Report_05.pdf Accessed 12 May 2014.

Note to Reader: There is some conceptual overlap between network access approaches and the network measures highlighted in Section 2.1. For example, measuring the number of intermodal facilities located within a 100-mile radius of a key node is similar in intent to measuring travel time to the nearest intermodal facility from a given origin zone. The former quantifies the density of intermodal exchange opportunities, while the latter seeks to more directly quantify the experience of a user in search of intermodal access. Similarly, a network access measure that quantifies travel time to the nearest interstate highway interchange for all zones will tend to move up and down with a network measure that counts the number of interstate centerline miles in a region. However, the network measure is constructed more as a density indicator (miles per square mile), while the area-based approach follows the classical accessibility formulation of "access for whom and to what."

Activity access approaches seek to quantify the specific activities that are accessible via the available transportation system (the W_i in Equation 1). The most common approach is to proxy activities by counts of population or employment within a given accessible area. Population most closely acts as a proxy for final demand while employment serves as a proxy for buyer and supplier firms. This generic approach could also be expanded to an industry-specific approach that would, for a given industry, target known categories of input suppliers and output consumers.

Impedance

The third choice for calculating an area-based accessibility measure pertains to the quantification of impedances – the barriers between the user group and the identified attractions/destinations. Here the analyst defines the approach along three dimensions: impedance quantification, network definition, and the functional form used to incorporate impedance values into the overall accessibility metric. Impedance can be quantified in units of travel time, travel cost, or generalized cost (which generally incorporates time, cost, and sometimes other relevant non-monetary costs of freight movements).

These costs must be then calculated on a selected network representation of the available transportation system, such as a network within a GIS-based system, travel demand model, or other routing software.[20]

Finally, the analyst must select a functional form with which to incorporate impedance values into the overall accessibility metric (the $f(c_{ij})$ in Equation 1). There are two common classes of functional forms adopted for accessibility measures: contour measures (also called cumulative opportunity, isochronic, or threshold measures), and potential/gravity-type measures. Contour measures count the attraction activities within a given impedance threshold from the point of origin. Thresholds are usually selected with some behavioral

[20] This memo does not consider straight-line distance-based calculation to be a desirable approach to accessibility measurement, as it fails to account for the opportunities and limitations presented by the actual transportation system (and thus does not support decision-making regarding transportation investments).

basis—e.g. using a three-hour threshold to capture the range for same-day truck deliveries. Potential measures, on the other hand, are continuous measures that count all activities in the region, weighted by a function of impedance. The chosen functional form of a gravity measure implies a particular tradeoff or equivalence between units of impedance and units of attraction (not necessarily 1 to 1). Utility-based measures are a special form of the more general gravity measure. They are based on discrete choice theory and represent the utility of available choices, with the choice set being the activities located in all other zones, and the utility function representing preference-based weighting of costs and attractions for a given entity (individual, industry). Utility-based measure are derived from the estimation process used in discrete-choice modeling and represent observed behavior.

> **Note to Reader**: A more detailed discussion of the various functional forms of accessibility measures (prepared for passenger rather than freight applications) can be found in the work by Bhat et al. performed for FHWA at the University of Texas at Austin.[21]

2.3 Data and Analytical Requirements

Planning and transportation practitioners require flexible assessment approaches that can be adapted to a variety of analytical and policy objectives, and to different levels of resource availability. The selection of an appropriate metric or set of metrics will depend both on the intended scale and subject of analysis and on resource considerations related to data availability and the time and budget required for measurement. This section describes the types and sources of data inputs used to calculate freight access metrics. Chapter 3 presents guidance on how to select a freight accessibility metric within the context of a broader evaluation approach.

Accessibility analysis is fundamentally concerned with the relationship between economic opportunities and transportation system performance. Therefore, all freight accessibility measurement approaches require transportation network data, along with information about how freight-related activities are distributed in geographic space.

Activity data is required for the calculation of activity access measures (see Figure 2). For example, one might quantify the employment accessible within a 3-hour radius of the selected origin point. Basic activity data such as population or employment are available from national sources including the US Census, Bureau of Labor Statistics, or Bureau of Economic Analysis. Population and employment estimates and projections may also be developed by states and MPOs as part of their long-range planning processes. Sometimes these data are already embedded within travel demand models. Alternate future

[21] See: *Development of an urban Accessibility Index: Formulations, Aggregation, and Application* (2002). Available at: http://www.utexas.edu/research/ctr/pdf_reports/4938_4.pdf, and *Urban Accessibility Index: Literature Review* (2000). Available at: http://www.utexas.edu/research/ctr/pdf_reports/4938_1.pdf

projections are also available from private data vendors such as Moody's Economy.com or IHS Global Insight.

Network data is used to calculate the impedances separating the target area from freight-related attractions or destinations. Network data is also used for infrastructure-based and network measures. To calculate travel times on the current road network, there are a number of approaches available: For States or MPOs using travel demand models, matrices of zone-to-zone travel times may be readily available as a byproduct of the modeling process. Without a travel demand model, analysts have a range of options including sketch planning approaches supported by online mapping tools such as Google Maps or MapQuest; the use of routing and market area tools embedded within commercial software such as ESRI ArcGIS or PC*Miller; and custom processing of national data sets including the Oak Ridge National Labs (ORNL) transportation networks and inter-county impedance matrices,[22] the National Performance Management Research Data Set (NPMRDS),[23] and the FHWA FAF^3 Network Database.[24]

Analysts may wish to restrict their analysis to certain subsets of the transportation network. For example, a network of truck routes could be constructed by selecting links that meet specified functional requirements for use by trucks (addressing issues such as turning radii, local regulations, bridge clearances, etc.). Depending on the level of detail desired, an analyst might also consider variation by time of day, to address changes in access caused by congestion or regulatory constraints (e.g. links within residential areas that are off-limits during the night).

Looking to the future, analysis of anticipated changes in accessibility require an extra analytical step. Changes in network impedances stem from changes in infrastructure, or from changes in demand patterns on the network. Sketch-planning, engineering estimates, and travel-demand models can all be used to translate information about the future condition of the transportation system and adjacent trip-generating activity into new estimates of network impedances and network performance.

Another issue of consideration for freight access measurement is the extent to which access across multiple modes can be captured by the adopted measures. Intermodal accessibility is most simply addressed with network access measures that quantify impedances on the road network between an origin point and important intermodal facilities such as ports or rail terminals. This avoids the need for additional data describing transit time and cost for rail, air, or water modes. On the other hand, by choosing this simplified approach one

[22] Center for Transportation Analysis, Oak Ridge National Laboratory. Transportation networks and Inter-county Impedance Matrices. Available at: http://cta.ornl.gov/transnet/index.html

[23] U.S. DOT Office of Freight Management and Operations. Vehicle Probe Data Set Information. http://ops.fhwa.dot.gov/freight/freight_analysis/perform_meas/#data

[24] FHWA Office of Freight Management and Operations. National Performance Management Research Data Set (NPMRDS): Technical Frequently Asked Questions. http://www.ops.fhwa.dot.gov/freight/freight_analysis/perform_meas/vpds/npmrdsfaqs.htm

accepts a more limited representation of freight transport choices and accessibility. Options do exist for building multimodal networks. For example, one might integrate GIS-based road and rail networks, with nodes that represent truck-rail terminals, and virtual links that represent the time and costs associated with transshipment. However, quantifying travel time and cost incurred in moving goods via rail, air, or water means addressing the issue of service schedules and varying or proprietary rates set by private operators. The Oak Ridge National Labs (ORNL) transportation networks and inter-county impedance matrices comprise a publicly available data set that does seek to quantify network impedances in comparable terms across multiple modes.[25] Yet another approach to quantifying modal availability is to compare the network coverage of alternate modal options – for example, by quantifying the amount of rail network mileage within a given geography.

One of the positive aspects of the systems used for freight accessibility calculations is that they are particularly well suited to mapping and visualization, in addition to the computation of numerical metrics. Because the process for calculating freight accessibility measures will in all but the simplest of cases occur in a GIS-based platform, minimal additional effort is required to map results in visual form, thus aiding in the communication, and even identification, of freight accessibility issues. Mapping can also enable those with local knowledge to identify calculation or data errors.

Note to Reader: A recent report by Caliper Corporation prepared for FHWA delves into many of the technical issue that may arise when using various types of network data to implement accessibility calculations.[26] This report, while focused on passenger- rather than freight-accessibility measurement, can serve as a resource for addressing challenges that are data-, rather than metric-definition-, related.

[25] Center for Transportation Analysis, Oak Ridge National Laboratory. Transportation networks and Inter-county Impedance Matrices. Available at: http://cta.ornl.gov/transnet/index.html

[26] Caliper Corporation. Transportation Planner's Web-Based Accessibility Toolkit, Draft Final Report. 2013. http://www.caliper.com/PDFs/Transportation-Planners-Web-based-Accessibility-Toolkit.pdf

3 GUIDANCE: STEPS FOR EVALUATING FREIGHT ACCESSIBILITY

Integrating information from previous chapters, this chapter presents a series of steps that can be used by an agency interested in evaluating freight accessibility for a state, region, or specific freight-generating location.

3.1 Step 1 – Describe the local and regional context

In a very broad sense, transportation planners and the communities they serve are concerned with freight accessibility because they are concerned with economic competitiveness. The desire to assess or monitor freight accessibility stems the desire to address both upsides and downsides of changes in accessibility, and thus the potential for changing economic competitiveness of freight-reliant industries.

Freight accessibility is only a relevant concept in relation to business reliance on goods movement. Freight accessibility can be threatened or enabled by changes in the cost or performance of freight access corridors, by changes in the structure of supply chains serving existing businesses, or by shifts in industry activity itself leading to new requirements for freight access to maintain economic viability.

Therefore, before embarking on actual measurement of freight accessibility, this report recommends first describing the local and regional context of the freight accessibility issue(s) in terms of:

(1) ***Geography***: what are the geographic bounds of the area of interest? Are there particular natural or geological features that affect the region's accessibility (e.g. mountains, rivers, geographic distance from major markets)?

(2) ***Economic Activity:*** what are they key industry sectors in your region of interest? What is known about their transportation requirements and current usage patterns (e.g. modal preferences, need for reliability, types of commodities moved)? Has the economic composition of your region shifted over time or is it expected to change in a way that will drive changing freight access requirements?

(3) ***Transportation Infrastructure:*** What are the key components of the transportation system serving your region or location of interest? Bear in mind that both last mile connectors as well as the backbone of the national freight system (e.g. the interstates and intermodal facilities) are likely to be relevant.

3.2 Step 2 – Describe the freight access issue

An agency's desire to assess freight accessibility may be triggered by one of two things: (1) the need to establish a baseline understanding of conditions, in order to track and respond to changes over time, and (2) a specific current or anticipated issue that is or may constrain freight accessibility.

In this stage of the process there are therefore two questions to be answered which will guide the subsequent selection of a measurement approach:

(1) What is the goal of measuring freight accessibility? Is the agency (a) looking for a set comprehensive measures that can be used to compare across geographies or over time, or (b) are there specific existing or anticipated issues at which the assessment is targeted?

(2) If specific freight access issues have been identified, what are their underlying causal factors? These may include issues related to last-mile connectivity, network coverage, modal availability, growth pressures and congestion, reliability, or shifts in industry or regional accessibility needs.

Note that an agency's need for freight accessibility measurement may in fact include both comprehensive measurement and targeted assessments, with the analysis proceeding from the more general to the more specific, in sequence.

3.3 Step 3 – Select a measurement approach

Having established the context and purpose of the assessment in Steps 1 and 2, Step 3 goes to the heart of the analysis: selection of an appropriate measurement approach. Here it is important to note that a measurement approach is less about selecting "the perfect metric" and more about designing an evaluation *process* that captures the issues of concern, is implementable with available data and analytical resources, and will provide policy guidance at the appropriate level of detail.

Summary Recommendations

The following are a set of summary recommendations regarding the selection of freight accessibility measurement approaches:

(1) Begin by identifying available activity and network data, as well as relevant tools such as GIS or transportation models.

(2) Consider prior analyses within the agency that have addressed freight accessibility or related concepts. Consider gaps in existing methods and their relevance to the problem at hand.

(3) Select an appropriate comparative framework that addresses the identified freight access issue (e.g. across time, different investment scenarios, or zones within a state or region).

(4) Consider the use of two types of measures: infrastructure-based or network measure that addresses the underlying causes of accessibility constraints, and area-based measure to capture the scope of the problem within a given comparative framework (across space, time, scenarios, or investment proposals).

(5) Choose an approach that matches the required level of detail for identified freight access issues. For comprehensive measurement approaches, simple metrics whose calculation can be automated and results easily communicated are best (e.g. network access measures and area-based countour measures). For targeted assessments of specific locations, measurements should be supplemented with more detailed evaluations based on stakeholder input or expert local knowledge.

With these high-level recommendations in mind the sections below describe in more detail the decision support provided by various measures, the types of comparative frameworks available, and how to match analysis objectives with level of effort, given available data and tools.

Available Data and Tools

As described in Section 2.3, all freight accessibility measurement approaches require some form of transportation network data, along with information about how freight-related activities are distributed in geographic space. When selecting measurement approaches, it is important to bear in mind existing data and tools available within an agency, as well as any prior efforts to quantify freight accessibility or related concepts.

Addressing the issues of computational complexity and data requirements, Table 16 through Table 18 in the appendix outline strengths and challenges of different specifications of area-based measures—in terms of the selected user group, attractions, and network impedances addressed.

Another consideration that dovetails with that of computational complexity is ease of interpretation. Both network access (e.g. travel time to the nearest rail terminal) and contour measures (e.g. employment within 180 minutes) are particularly attractive along these dimensions because they are both relatively easy to calculate and to explain. In contrast, potential/gravity measures such as the Effective Density measure used in the United Kingdom’s Department of Transport (DFT) project evaluation guidance are less easy to generate and to interpret and have no intuitive units of measurement. It is for these reasons that the case studies in Chapter 4 demonstrate contour measures but not the more complex potential/gravity measures. Those interested in the Effective Density measure can refer to the Strategic Highway Research Program Project C11 for additional guidance.[27]

Decision Support and Comparative Frameworks

Chapter 2 introduced broad categories of measure relating to freight accessibility: infrastructure-based, network, and area-based measures. These measures each provide a different type of information and decision support to an agency or analyst.

Infrastructure-based measures focus on the mobility associated with transportation infrastructure or services and overlap with other categories of performance. Thus, they are best suited to identifying and quantifying sources of freight accessibility constraints. Network coverage and completeness measures can similarly be used to identify accessibility constraints. However, unlike infrastructure-based measures applied to individual links or sets of links, network measures highlight constraints that derive from the connectivity, coverage, or directness of the transportation network within a particular area. Area-based measures, on the other hand, are blind to the cause of an access issue. Instead, they are uniquely suited to comparative analyses that help decision-makers assess the severity of a given access constraint for a particular area or industry cluster.

Table 4 presents a set of comparative assessments approaches that can be implemented with accessibility measures, and their potential decision-making uses.

Because of inherent differences between infrastructure- and area-based measures, many situations will require both approaches to assess and document a freight accessibility issue. The use of multiple kinds of metrics side-by-side is demonstrated in the case studies in Chapter 4.

[27] Available at: http://tpics.us/tools/

Table 4 Comparative assessment approaches and potential decision-making uses

Comparative assessment types	Decision support
Differences in access… …by mode …between geographic areas …between congested and uncongested conditions …at the 95th and 50th percentile of travel times …over time …to identified industry-specific inputs or modal needs (e.g. access to supplier industries or to an grain elevator) …relative to competitors …with and without a proposed service level change (for marine, air, and rail connections)[28] …with varying scenarios of future growth …with and without a proposed project	- Baseline characterization - Definition of need - Long-range planning - Target setting - Progress tracking - Prioritization - Project evaluation

Objectives, Detail, and Level of Effort

In Step 2 (above), the analyst or agency was asked to identify the goal of the freight accessibility evaluation. This statement of objectives directly relates to the choice of metrics and analytical procedures:

Comprehensive Measurement

Comprehensive measurement approaches are typically required within long-range planning or prioritization processes. Access measures can be used to conduct baseline evaluations and establish an understanding of relative need across a metropolitan area, state, or multi-state region. They can also be used to track changes in accessibility over time, or to assess the relative success of different proposed projects at addressing existing access issues within a project rating system.

To meet the objectives of a comprehensive assessment, agencies require reproducible and comparable approaches that are manageable in terms of time and data requirements, match key policy objectives, and are instructive relative to the available policy levers. Additionally, for these types of broader assessments it is preferable to adopt relatively generic metrics that match the diversified freight needs of businesses across a region.

For example, if a state is primarily interested in facilitating longer distance inter-regional, national, or international trade and wishes to conduct comparative evaluations across zones within the state, they can choose measures that quantify travel times to key nodes in the network such as interstate ramps, rail terminals, or ports. Using such measures within a

[28] Note: this usage assumes a choice of accessibility indicator that uses some measure of service levels (# of services per day, # of destinations reachable, etc.) as the activity variable in the accessibility metric.

baseline assessment will help identify focus areas for more detailed assessments of available improvement options. The Appalachian Region case study in Chapter 4 (Section 4.3) provides an example of this approach.

Alternately, if a state or MPO feels comfortable collecting key activity data such as employment (either total, or by sector), then they might choose measures that quantify the amount of freight-related business activity accessible within a certain impedance threshold (See the North State case study in Section 4.4 for one example of this). Yet another option would be to first identify key freight-generating locations and then to apply a uniform set of performance measures to these key locations across a state or region. This approach has the benefit of being targeted at known locations of interest and being responsive to stakeholder inquiries, but the drawback of requiring an additional selection methodology, or reliance on local knowledge (thus raising comparability issues across areas and analyses undertaken at different times).

Targeted Assessments

Evaluation approaches and metrics tailored to individual sites and projects differ in a number of ways from assessment approaches designed for consistent application across a state or region. Detailed project or site-level analyses are by their very nature specific to a given user group and set of infrastructure assets. At more localized geographic scales practitioners will also have greater access to stakeholders and/or commodity-flow data. Aggregate metrics like those used in planning or prioritization are useful for initial assessments but are unlikely to be sufficient for fully characterizing accessibility and access constraints for a particular site. Local knowledge can be leveraged to focus on target industry needs in terms of modal access requirements, commodity-specific transportation performance needs (reliability, speed), accessibility to markets relative to competitors, and key origins and destinations for freight flows generated by the location. The use of local knowledge is as much a planning exercise as it is a matter of applying specific measurement approaches. The Delaware case studies presented in Sections 4.1 and 4.2 are examples of situations that require more targeted assessments.

3.4 Step 4 – Implement the Selected Measurement Approach

In Step 4, the analyst implements the selected measurement approach and examines the results for lessons learned—including lessons about the ability of the adopted metrics to capture issues identified by planners and stakeholders, and the policy implications of the measurement results. Rather than discuss potential insights in the abstract, the following chapter presents the results of four separate freight accessibility and measurement cases studies.

4 CASE STUDIES: FREIGHT ACCESSIBILITY EVALUATION

This chapter presents case study examples of freight accessibility issues, as perceived by transportation and planning practitioners "on the ground." Each case study follows the basic analytical structure defined in Chapter 3, a process designed to identify, characterize, and measure existing or anticipated freight accessibility issues. The steps followed for each case are as follows:

(1) Describe the local and regional context of the freight accessibility issue(s) including identification of affected economic sectors and relevant transportation infrastructure;

(2) Describe the current or anticipated freight access issue(s) and its (their) underlying causal factors. These may include issues related to last-mile connectivity, network coverage, modal availability, growth pressures, reliability, or shifts in industry or regional accessibility needs. (Note: in some cases there may be no one issue of interest, but a more general need to track relative performance across areas).

(3) Select a measurement approach. Factors to consider include: metrics used in prior analyses, available data and tools, the scale of the analysis or required level of detail, and an appropriate comparative framework (e.g. across regions, scenarios, modes, or time periods) for the issues at hand.

(4) Implement the selected measurement approach. Describe how calculated metrics capture the identified issues and outline policy implications.

The overall objective is to select a measurement approach and set of metrics that can capture the access issue of interest and support ongoing planning, prioritization, and project evaluation efforts. The chapter documents four separate case studies addressing a variety of freight accessibility issues:

(1) **Port of Wilmington, Delaware** – this case examines anticipated growth pressures as well as issues of land use compatibility and last-mile access;

(2) **Manufacturing Facility, Seaford, Delaware** – this case addresses the interdependence of rail, barge, and truck access for a manufacturing site in the city of Seaford, Delaware.

(3) **Appalachian Region** – addressing a broad multistate region, this case considers access related issues across multiple scales and modes within Appalachia, which has historically faced isolation from major metropolitan areas and ports.

(4) **North State Super Region, California** – this case details terrain-, remoteness- and infrastructure-related access constraints faced by the North State Super region of California.

The first two cases cover specific locations within the state of Delaware that were identified as locations-of-interest for freight accessibility by the Wilmington Area Planning Council (WILMAPCO). These cases make use of recent freight modeling efforts within the Delmarva Peninsula to examine freight network performance under alternate future scenarios affecting freight volumes and modal flows within the region. The third case study draws on existing analyses prepared for the Appalachian Regional Commission and highlights the use of network access measures to quantify county-level access to the national freight system. The fourth case study applies both infrastructure-based and area-based freight accessibility metrics to capture multiple aspects of identified freight accessibility issues including network coverage and the scale of the accessible buyer-supplier market.

Together, these cases illustrate the range of area, corridor and modal accessibility dimensions that were introduced earlier in this report. They cover a variety of scales, from local access roads to issues of broad regional accessibility. Additionally, the cases cover rural, small city, and major metropolitan area contexts and address interactions between truck and other freight modes.

4.1 Port of Wilmington (South Wilmington, DE)

The Port of Wilmington case study is based on material provided by the Wilmington Area Planning Council (WILMAPCO), the MPO that includes the Port of Wilmington, Delaware. As understood by WILMAPCO, key freight access issues for the port are those related to usage of local access roads, anticipated growth pressures, and community concerns. Like many ports, the Port of Wilmington is located in an urban area, adjacent to residential neighborhoods that raise issues of land use compatibility and challenge planners to provide adequate truck access while trying to minimize negative environmental effects on surrounding communities. In addition, potential growth trends at the port and its surrounding environs may in the future impose additional pressures on the transportation system, leading to further constrained accessibility for this key gateway.

This case explores access concerns related to anticipated growth pressures as well as issues of land use compatibility and last-mile access. The case study analysis then makes use of recent freight modeling efforts within the Delmarva Peninsula to examine freight accessibility for alternate future scenarios with different assumptions about growth patterns and activity levels at the port. The results are presented as a representative example of comparative access evaluations across alternative futures.

Local and Regional Context

> ***Step 1:***
> ***Local & Regional Context***
>
> ☑ Describe local and regional geography
>
> ☑ Identify affected economic sectors
>
> ☑ Identify relevant transportation infrastructure

The Port of Wilmington is located at the confluence of the Christina and Delaware rivers, approximately 30 miles downstream from Philadelphia and 70 miles from the Atlantic Ocean. Wilmington was the 66th busiest U.S. port in 2013, exporting approximately $3.1 billion worth of goods and importing nearly $10.1 billion worth of goods during the year. As identified by the recently published Delmarva Freight Plan, the Port of Wilmington functions within a number of the peninsula's major supply chains including:[29]

(1) The energy supply chain, handling both petroleum and specialized equipment for the wind energy market;

(2) The food products supply chain, importing tropical fruits, juices, and concentrates for brands such as Dole and Chiquita; and

(3) The transportation equipment supply chain, with AutoPort, Inc. at the port serving vehicle preparation needs for auto exports, as well as a dedicated deepwater Auto & RoRo (roll-on/roll-off) berth.

The top imports to the Port (by value) are mineral fuels and fruit (bananas and other perishable items), and the top export commodities are vehicles and mineral fuels.[30] Serving these specialized transport needs, the port offers large dock-side refrigeration facilities and a dedicated berth for auto and RoRo freight vehicles.[31] While Norfolk Southern and CSX provide rail service at the port, perishable products such as fruit leaving the port are dependent on truck freight for on-time delivery without spoilage.

In terms of National Highway System access, the port is located adjacent to I-495 and I-295, both of which connect to I-95 nearby. Primary truck access to the port is provided by Terminal Ave., a four-lane road with on- and off-ramps to I-495 a half a mile from the port entrance. Christiana Ave. serves as a secondary route to the port, and provides access to downtown Wilmington via U.S. Route 13. State Route 9, which intersects with Terminal Ave. west of the port entrance and connects with I-295, also serves as an important route for freight traffic (see Figure 3). In the immediate vicinity of the port are several collector

[29] Delmarva Freight Plan. Final Draft Report March 2015. http://www.wilmapco.org/freight/Delmarva/Delmarva_Freight_Plan_2015.pdf

[30] WISERTrade. State Exports by Port Database. http://www.wisertrade.org/home/portal/index.jsp; and Loyd, Linda. Expansion proposed for Port of Wilmington on the Delaware. http://articles.philly.com/2012-05-21/business/31789043_1_stevedoring-firm-port-contractors-port-richmond. Accessed 17 June 2014.

[31] The Port of Wilmington Delaware. Our Facilities. http://articles.philly.com/2012-05-21/business/31789043_1_stevedoring-firm-port-contractors-port-richmond Accessed 10 June 2014.

roadways, which each carry between 500 and 1,100 truck trips per day, as well as residential neighborhoods and a variety of industrial uses.

Freight Access Issues

> ***Step 2:***
> ***Freight Access Issue***
>
> ☑ Describe current or anticipated issues
>
> ☑ Identify causal factors or key performance issues

WILMAPCO identified both current freight access issues and anticipated issues or risk factors related to future growth pressure at and near the port.

Truck Usage of Local Roads

Truck queuing and use of local roads are current high-profile last-mile access issues for the port area—both issues that were brought to light by the *Port of Wilmington Truck Parking Study*.[32] According to Daniel Blevins, a planner with the Wilmington Area Planning Council (Wilmington's MPO), trucks line up along Terminal Ave., waiting to enter the port during peak periods.[33] Community leaders also report truck idling for "several hours overnight" near Terminal Ave.'s interchange with I-495.[34] The community is concerned with truck idling because of negative environmental quality and health impacts.[35] The queuing problem is ameliorated to some degree by the use of RFID tags—which allow drivers to enter the port quickly—but compounded by the absence of a traffic light at the intersection of Terminal Ave. and Christina Ave., and the resulting traffic attempting to turn onto (or off of) Terminal Ave. Truck counts during the early morning period before the port opens show concentrations along Terminal Ave. and also on and around Pigeon Point Rd., a north-south connector (see Figure 4).

Anticipated Growth Pressures

The Port of Wilmington and its surrounding environs are the subjects of ongoing discussion regarding possible port expansions as well as new development of warehousing, logistics, and other industrial activities. The port sits on a 300 acre site with access on the Christina River, which only accommodates ships requiring channel depths of 38 feet or less. The Delaware River navigation channel, on the other hand, is being maintained at 45 feet. Current and anticipated shifts in global shipping patterns have led to interest in deeper channels to serve larger vessels, and in expanded capacity at the port more generally.

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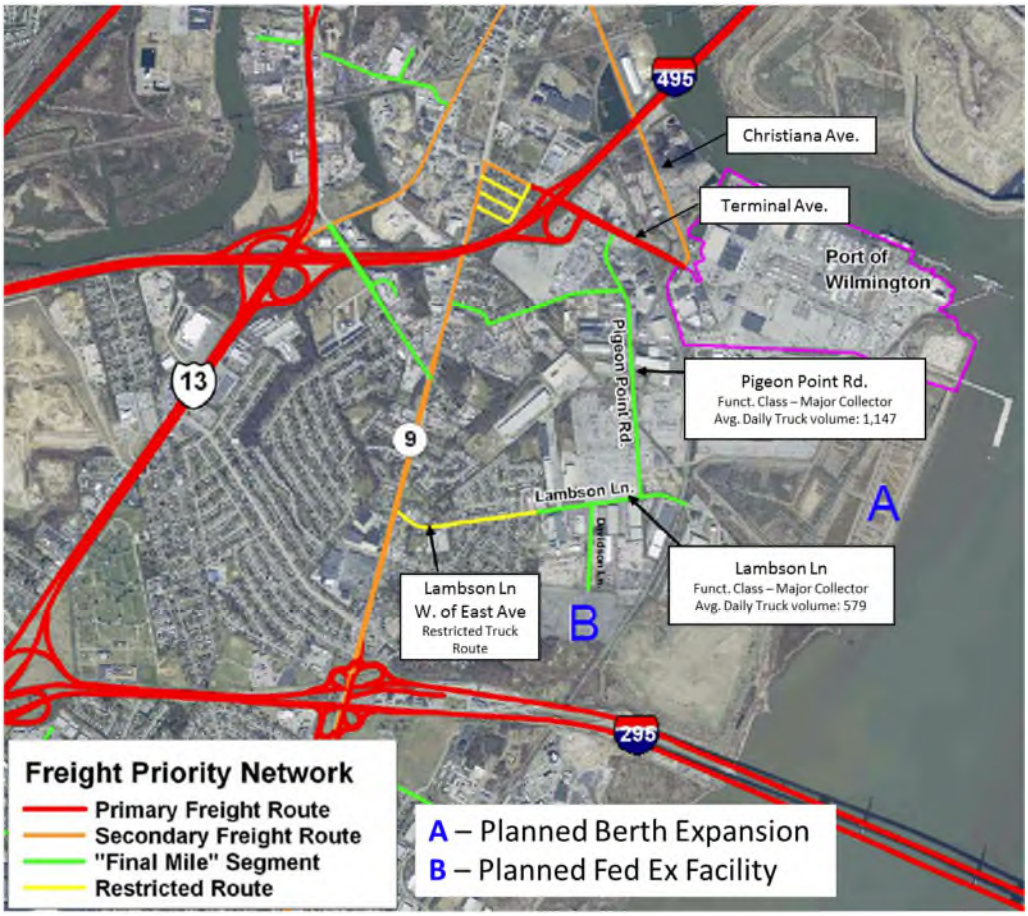
32 Port of Wilmington Truck Parking Study, July 2013, Wilmington Area Planning Council, http://www.wilmapco.org/truckparking/Port_Final_July14.pdf, page 29.

33 Daniel Blevins, phone conversation, May 8, 2014.

34 Port of Wilmington Truck Parking Study, July 2013, Wilmington Area Planning Council.

35 Port of Wilmington Truck Parking Study, July 2013, Wilmington Area Planning Council, page 29.

Figure 3. Port of Wilmington



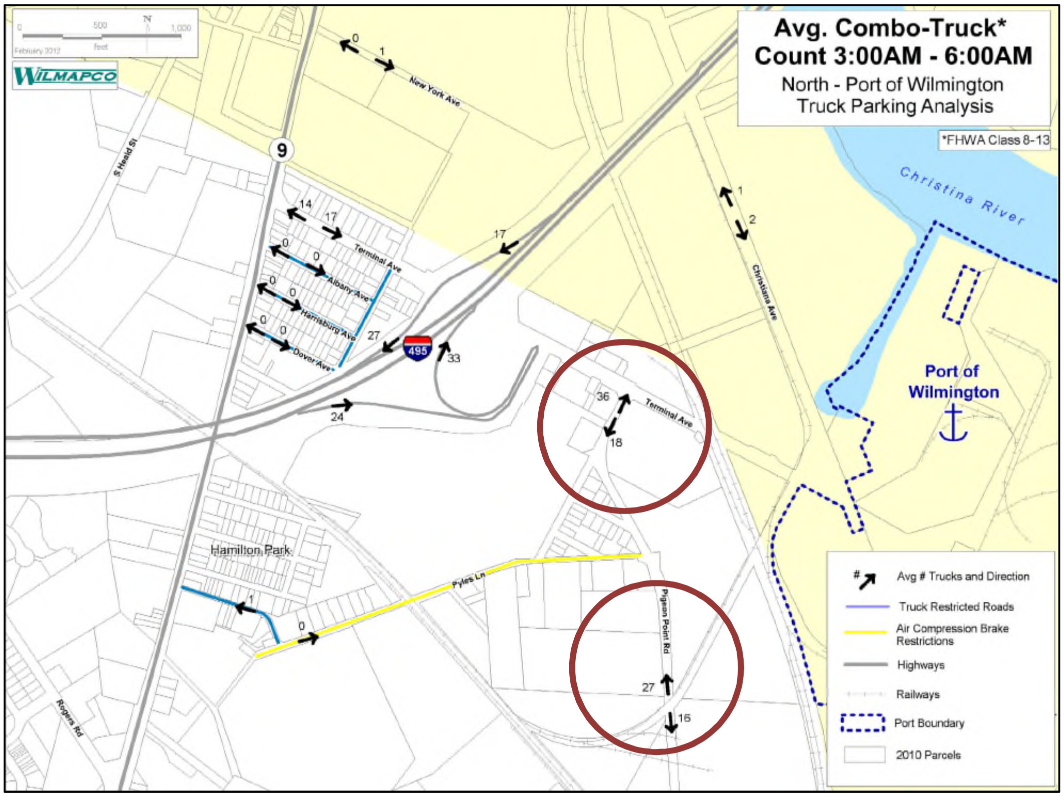
Source: Wilmington Area Planning Council

To this end, the following expansion options have been proposed:

- A planned berth expansion along the Delaware river (Point A in Figure 3)[36]
- Expansion at the former riverside Pigeon Point Landfill just north of the Delaware River Bridge
- Redevelopment of the former Evraz Claymont steel site north of the port in Claymont for additional port activities
- Redevelopment of the vacant 176-acre vacant Riveredge industrial park south of the Delaware River[37]

[36] Loyd, Linda. Expansion proposed for Port of Wilmington on the Delaware. May 2012. http://articles.philly.com/2012-05-21/business/31789043_1_stevedoring-firm-port-contractors-port-richmond. Accessed 10 June 2014.
[37] Montgomery, Jeff. State plans wide-ranging look at port sites, expansions. Delaware Online. http://www.delawareonline.com/story/news/local/2015/08/07/delaware-port-study/31286661/

Figure 4. Early Morning Combination Truck Movements around the Port of Wilmington



Source: Port of Wilmington Truck Parking Study, Wilmington Area Planning Council

The planned berth expansion along the Delaware River would occupy land immediately south of the port that is currently accessed using Lambson Lane, part of which passes through a residential neighborhood and has truck restrictions (see Figure 5). In addition, a new 183,000 FedEx distribution facility has been proposed at Davidson Lane, a small collector roadway that intersects with Lambson Lane.[38]

In general, the potential for growth on and near the port carries with it a risk for increased limitations on truck accessibility in the future. This includes highly localized issues on local roads, as well as the potential for broader congestion related effects. Because many of the streets connecting the port to S.R. 9 have truck use restrictions (Figure 5), freight access will very likely be affected by an increase in traffic. Moreover, if pavement conditions are allowed to deteriorate due to a lack of state funding, freight access could become more difficult as traffic increases.

The next section of this case study will focus on using modeled scenarios to examine potential risk factors related to future development of additional freight-generating

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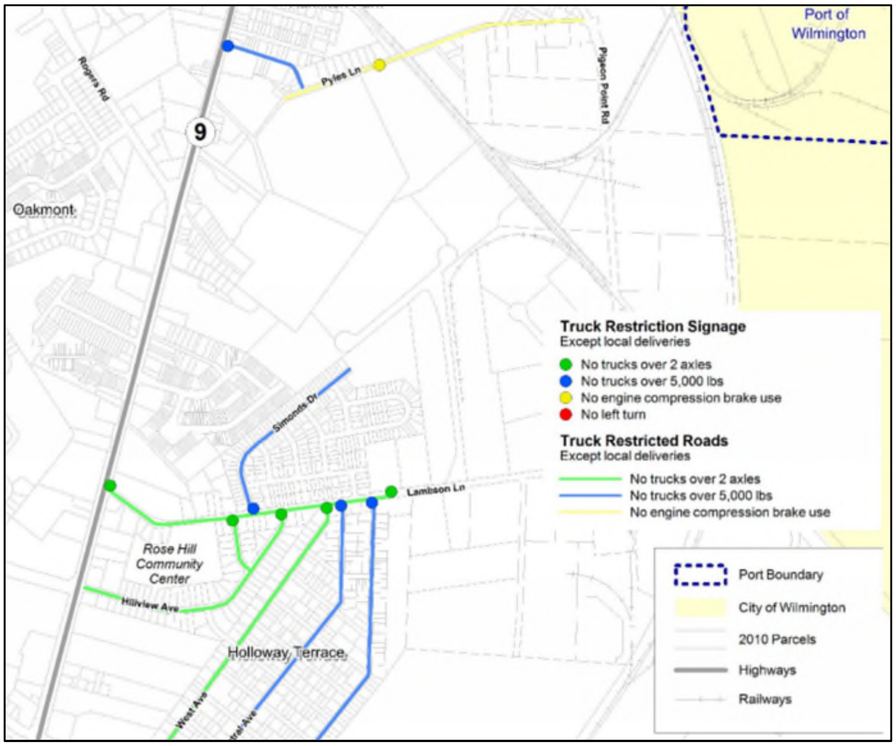
[38] Nathans, Aaron. FedEx plans New Castle County warehouse. August 2013. http://www.delawareonline.com/article/20130829/BUSINESS06/308290018/. Accessed 10 June 2014.

activities. Given the importance of local concerns regarding truck traffic near the port, modeling and freight accessibility measurement can only ever serve as one part of broader planning and engagement for the port area.

Figure 5. Truck Restrictions in Residential Areas Surrounding the Port of Wilmington



Source: Port of Wilmington Truck Parking Study, Wilmington Area Planning Council

Freight Accessibility Measurement

The freight accessibility issues highlighted in this case can be summarized as follows:

- The case zeroes in on “last-mile” access between the national highway system and a major freight generator, in this case the Port of Wilmington, Delaware.
- Constraints on accessibility are of concern due to growth pressures in the area. Growth can lead to congestion, which in turn may impact overall accessibility of the port for trucks, by creating localized delay. Growth may also lead to pavement degradation if the maintenance budget does not keep pace with increases in heavy truck traffic.

Step 3:
Select Measurement Approach

- ☑ Consider prior analyses
- ☑ Select an appropriate comparative framework
- ☑ Identify available data and tools
- ☑ Choose an approach that matches the required level of detail for identified freight access issues.

- A key policy concern for maintaining adequate accessibility levels at the port is the resulting negative impacts on (and pushback from) the surrounding residential communities. Effort to maintain adequate local access for trucks will require a coordinated effort to minimize environmental consequences related to emissions and truck idling.

Given the interest in growth pressures in the Port of Wilmington area, this case presents a need for comparisons of freight accessibility across alternate future scenarios.

Prior Analyses

At present, the types of local access issues that have been identified by WILMAPCO are discussed in terms of performance measures such as truck volumes on residential streets, the number of trucks parking overnight, air quality measures, pavement quality measures, and measures of queuing.

In the future, with the anticipated growth in the port area, travel time and reliability issues may constrain the size of the local one-day delivery market for the port (a measure of accessibility), which would affect its competitiveness, particularly given the importance of perishable produce imports to the Port of Wilmington.

The recently completed Delmarva Freight Plan offers modeled economic and freight infrastructure scenarios that can be used to investigate growth pressures in the Port of Wilmington area. The Delmarva Freight Plan is a multi-state, multi-regional, and multi-modal evaluation of the freight system on the Delmarva Peninsula. The plan was supported by 3 DOTs (Delaware, Maryland, and Virginia) and 2 MPOs (WILMAPCO and the Dover/Kent County MPO), with Delaware DOT serving as the lead. The freight plan process included development of a Cube Cargo model, and assessment of six scenarios specified to explore ongoing "what if" issues based on outreach and planning insights within the region. With a horizon year of 2040, the scenarios incorporate both economic assumptions about the rate and location of freight-generating activity growth, and infrastructure assumptions regarding the availability of multimodal freight transportation services. The outputs of the model include a select set of area-based access measures, as well as infrastructure-based performance data such as Level of Service (LOS).[39]

Selection of Metrics

To assess growth in the Port of Wilmington area, this case study builds on data from two Delmarva Freight Plan scenarios: 2040 Trendline and 2040 Multimodal Enhancement with Accelerated Growth. The 2040 Trendline scenario represents a baseline assessment of population and employment growth consistent with current trends. It provides a reference point against which to compare alternative futures. The 2040 Multimodal Enhancement Scenario with Accelerated Growth includes two types of adjustments relative to the baseline:

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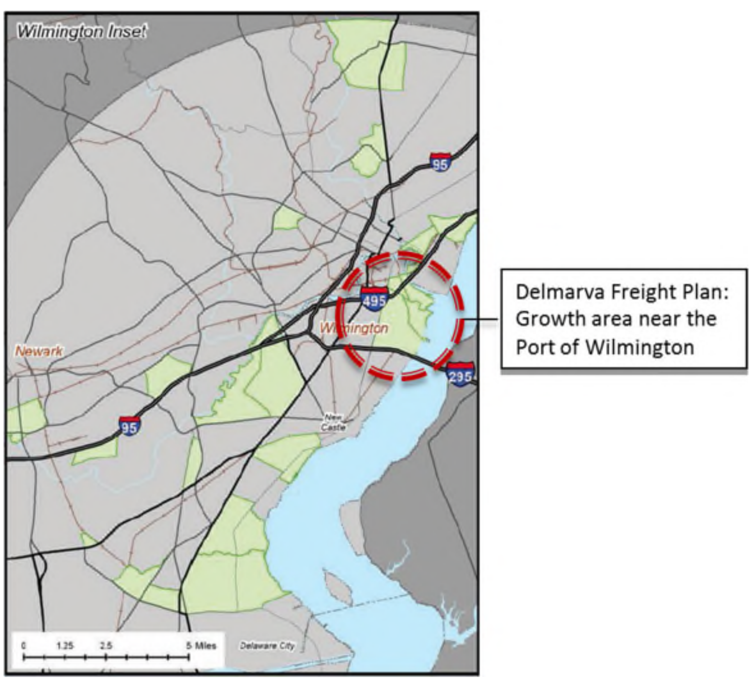
[39] Delmarva Freight Plan. Final Draft Report March 2015.

(1) **Multimodal Enhancements**: the scenario models enhancements to the multimodal transportation network including rail, waterways, intermodal facilities, and ports. One specific enhancement built into this scenario is development of a new container facility at the Port of Wilmington.

(2) **Accelerated Growth**: the scenario generates commodity flows based on more aggressive growth assumptions for the Delmarva Peninsula. The assumptions including background population, household, and employment growth at a 20% improved rate compared to the Trendline forecasts; 40% improved growth rate for target industries (food manufacturing, petroleum and coal products, chemical manufacturing, fabricated metals, transportation & utilities, and wholesale trade); and some additional adjustments for market shifts and productivity factors. Population and household growth is spatially distributed in proportion to existing settlement patterns. Employment growth, on the other hand, is manually allocated to growth areas that correspond to existing major employment and freight hubs, as well as anticipated growth areas based on local knowledge and available economic development policy instruments (Figure 6). Overall the accelerated growth scenario corresponded to a 38% increase in employment relative to 2010 values, compared to 30% in the Trendline forecasts.[40]

Figure 6 Accelerated Employment Growth Areas in the Vicinity of the Port of Wilmington



Source: Adapted from the Delmarva Freight Plan.

[40] Delmarva Freight Plan. Final Draft Report March 2015.

Note that while these scenarios were not constructed for the sake of analyzing freight access issues at the Port of Wilmington, specifically, they are valuable analytical resources of the type that may be developed within state freight planning efforts and as such support a useful demonstration case of freight accessibility measurement.

Using available model data, this case study compares freight accessibility between the baseline and alternate growth scenario, using a combination of infrastructure-based and area-based measures:

- Network level of service on key facilities providing access to the Port of Wilmington (an infrastructure-based measure)
- Employment accessible from the Port of Wilmington (an area-based activity access measure)

These metrics are selected based on available model outputs to capture both the underlying cause of freight accessibility issues (namely: congestion from increases in freight-generating economic activity) and the economic implications of the constraints on market size for the Port of Wilmington.

Implementation of Selected Metrics

Step 4:
Implement Measurement Approach

☑ Calculate selected metrics

☑ Describe relationship between metrics and identified issues

☑ Consider policy implications

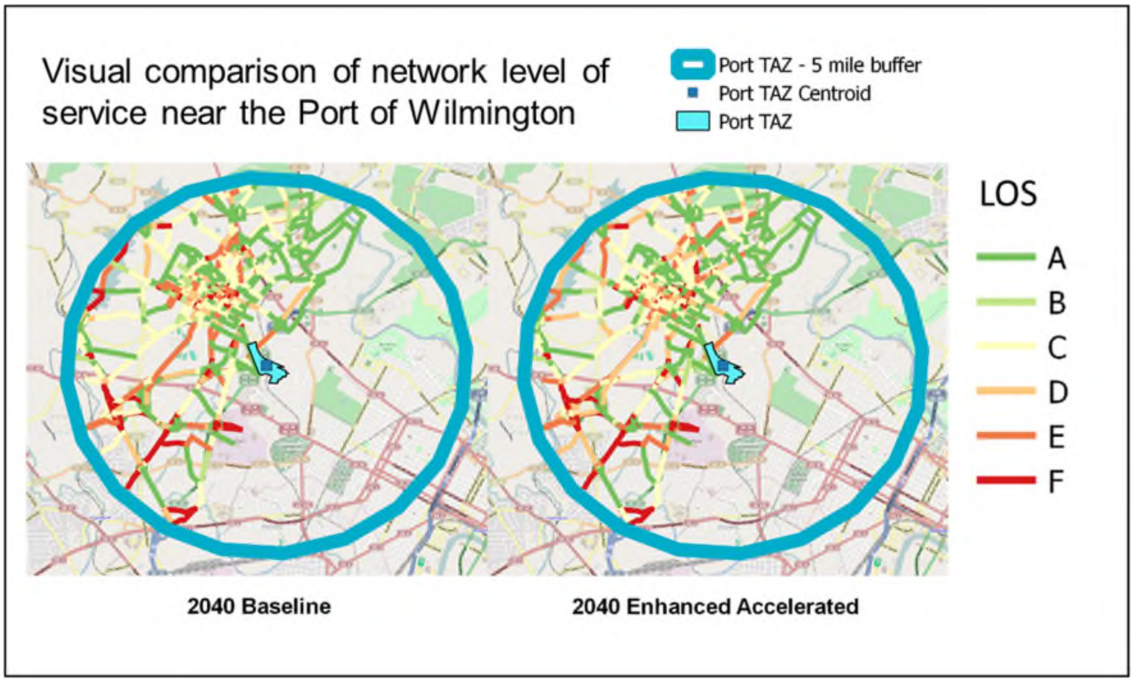
One set of outputs from the freight modeling exercise within the Delmarva Freight Plan is the forecast level of service (LOS) for each roadway link in the network, under the 2040 Trendline and 2040 Multimodal Enhancement with Accelerated Growth scenarios. This is an infrastructure-based measure than can be used to examine congestion-related effects on the network.

Figure 7 maps LOS under both scenarios within a 5 mile radius area around the port. Visual inspection does not reveal strong differences between the two scenarios. To further quantify minor variations in LOS, the LOS designation of each link was converted into a numeric score, as shown in Table 5. This numeric score was then used to develop aggregate statistics about the "last-mile" network serving the port. As can be seen in Table 6, the average level of service on the network in the immediate vicinity of the port does decrease slightly between the Trendline scenario and the scenario with additional growth at and around the port. This finding validates some level of concern regarding congestion effects from future growth pressures. The difference between scenarios, however, is relatively minor. Given that the growth scenario developed as part of the Delmarva Freight plan was not focused exclusively on port-area changes, it is unsurprising that network effects are not drastic but rather comprise a variety of minor shirts in performance across the entire peninsula.

Table 5 Conversion of LOS measure into a numeric score

LOS	Numeric score
A	6
B	5
C	4
D	3
E	2
F	1

Figure 7 Roadway Level of Service within 5 miles of the Port of Wilmington



Source: EDR Group Analysis using QGIS and LOS data from the Delmarva Cube Cargo model.

Table 6 Weighted average LOS within a 5 mile radius of the Port of Wilmington

Measure	2040 No-Build	2040 Enhanced Accelerated	% Change from No-Build
Weighted average LOS score - by truck volumes	2.69	2.60	-3.32%
WEIGHTED average LOS score - by distance	4.24	4.12	-2.75%

Source: EDR Group Analysis using QGIS and LOS data from the Delmarva Cube Cargo model.

Another output metric derived from the Delmarva Freight plan is the total employment accessible within 20 minutes of the Port of Wilmington. This metric is still a highly-localized measure of access and therefore does not fully address the full market reach of the port as a measure with a higher travel time threshold (e.g. 180 minutes) might. It does, however, begin to address the “access to what” component of the accessibility issue. As can be seen in Table 7 and Table 8, the accessibility of the port is sequentially reduced by growth pressures between the modeled scenarios.

Table 7 Employment within 20-minutes of the Port of Wilmington

Accessible Activity	2010 Base	2040 No-Build	2040 Enhanced	2040 Enhanced Accelerated
Service Employment	252,562	259,515	252,340	247,674
Industry Employment	47,561	40,264	38,808	38,621
Total Employment	**300,123**	**299,779**	**291,148**	**286,295**

Source: Delmarva Cube Cargo model.

Table 8 Percent change between scenarios – employment within 20 minutes of the Port of Wilmington

Accessible Activity	2010 to 2040	2040 No-Build to 2040 Enhanced	2040 No-Build to 2040 Enhanced Accelerated
Service Employment	2.8%	-2.8%	-4.6%
Industry Employment	-15.3%	-3.6%	-4.1%
Total Employment	**-0.1%**	**-2.9%**	**-4.5%**

Overall, the infrastructure-based and area-based measures calculated above do validate, to some degree, the identified concerns with growth pressures on localized port access. However, the case study results also highlight the limitations of high-level analysis for addressing accessibility concerns at an individual site. While large-scale scenarios of the type developed in a long-range planning exercise can be useful first steps in assessing site-specific issues, they are no substitute for more specific analysis of accessibility constraints for a given industry or freight cluster—either based on more detailed modeling or on stakeholder input.

4.2 Manufacturing Facility (Seaford, DE)

Also based on input from WILMAPCO, this case addresses the interdependence of rail, barge, and truck access for a manufacturing site in the city of Seaford, Delaware. As in the Port of Wilmington example, this case builds on outputs from the Delmarva Freight Plan to consider the implications of future scenarios on freight accessibility.

Local and Region Context

> ***Step 1:***
> ***Local & Regional Context***
>
> - ☑ Describe local and regional geography
> - ☑ Identify affected economic sectors
> - ☑ Identify relevant transportation infrastructure

As described by the Delmarva Freight Study, the City of Seaford is a center of industrial freight-generating activity on the Peninsula because of its strategic multimodal connections:

> Within Sussex County, Delaware, the City of Seaford is an important trade capital given its proximity to US 13 and access to the Nanticoke River. Corporations have set up industrial hubs in Seaford to take advantage of linkages to major metropolitan areas such as Wilmington and Norfolk.[41]

This case study focuses specifically on the Invista manufacturing site in Seaford, as a particular example of a firm that depends on multimodal accessibility and is therefore vulnerable to potential future reductions in service.

Invista is a Kansas-based manufacturer of chemical, polymer, and fiber products with over 60 locations worldwide.[42] On a 750-acre property just south of Seaford, Delaware, Invista produces performance surfaces and materials for a variety of commercial, residential, automotive, and industrial uses. Invista's southern Delaware facility is bordered by the Nanticoke River to the east and Norfolk Southern's Delmarva Secondary railroad to the north.[43] Truck access to the facility is provided by Woodland Rd., a major collector roadway, and Nanticoke St., a local roadway. These local collector roads provide "last-mile" connectivity to Delaware Route 20 (SR 20), which in turn provides access to US Route 13, part of the National Highway System (see Figure 8). Other manufacturers including Eastern Sheet Metal, American Precast Inc., and Gardner Asphalt are also located adjacent to Invista, along the railroad line. The manufacturing cluster benefits from rail and barge access, which supports lower-cost movement of heavy commodities such as chemicals, fuel, metal, sand and gravel.[44] At Seaford, Norfolk Southern also interchanges with one of the peninsula's Maryland & Delaware Railroad (MDDE) shortline rail segments.[45] Located just

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[41] Delmarva Freight Plan. Final Draft Report March 2015. Page 16.

[42] Invista. http://www.invista.com/en/index.html. Accessed 10 June 2014.

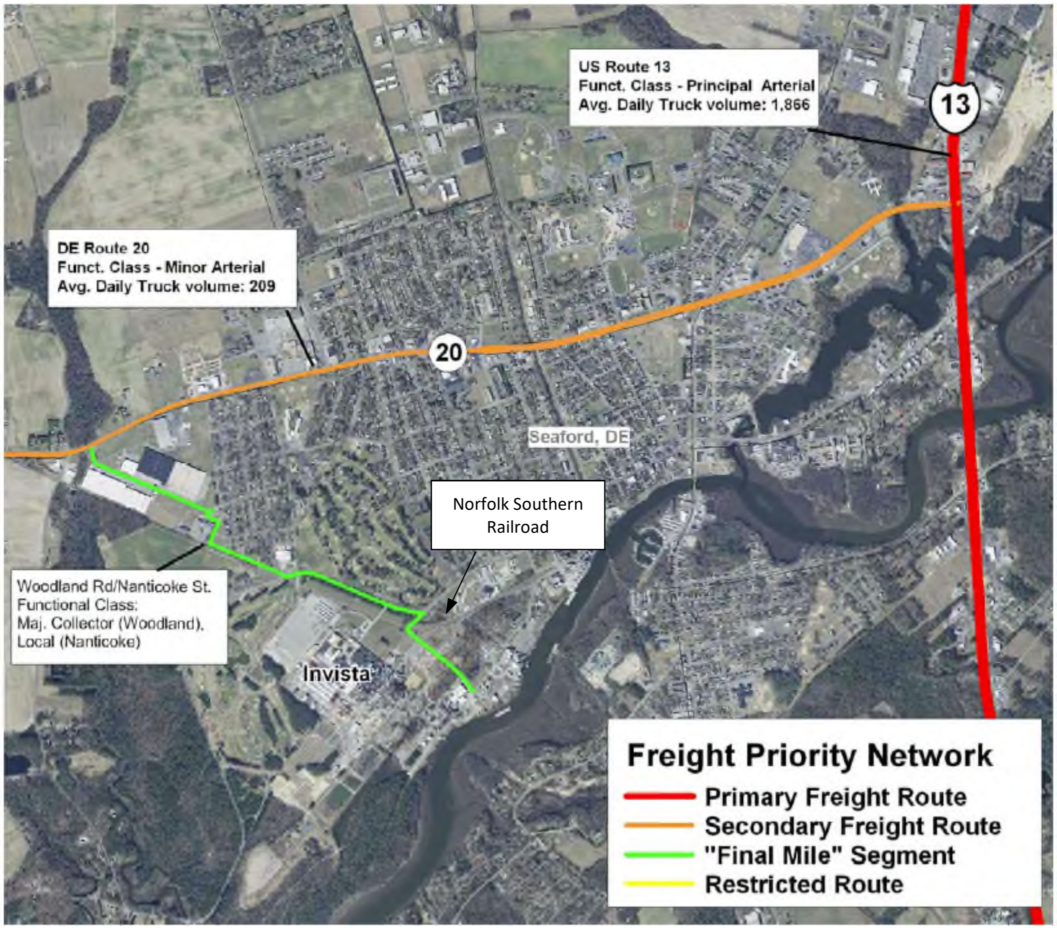
[43] US EPA. Invista Seaford Plant. July 2011. http://www.epa.gov/reg3wcmd/ca/de/webpages/ded002348845.html; Invista. Performance Surfaces and Materials. 2013. http://www.invista.com/en/businesses/performance-surfaces.html. Accessed 10 June 2014; and Delaware DOT. Delaware State Rail Plan. 2011. http://www.deldot.gov/information/pubs_forms/srp/srp_final.pdf Accessed 9 September 2015.

[44] See Army Corp of Engineers. Waterborne Commerce of the United States: Part 1 – Waterways and Harbors Atlantic Coast. 2011. http://www.navigationdatacenter.us/wcsc/pdf/wcusatl11.pdf. Page 94.; and Greater Seaford Chamber of Commerce. Take Five. June 2010. http://www.seafordchamber.com/pdfs/10_june.pdf. Accessed 12 June 2014.

[45] Norfolk Southern System Map. http://www.nscorp.com/content/dam/nscorp/maps/System-Map/ns-system-map.pdf Accessed 4 September 2015.

north of Route 20 is another cluster of freight-generating businesses in the Seaford Industrial Park, including a number of chemical manufacturers.[46]

Figure 8. Invista and Downtown Seaford



Source: Wilmington Area Planning Council

Freight Access Issues

According to Mr. Blevins (WILMAPCO), Invista ships and receives product via the Norfolk Southern railroad and via barges along the Nanticoke River, which originates in Seaford and terminates in Chesapeake Bay (see circle in Figure 9, which surrounds Seaford). It also depends heavily on the access provided by US 13.

Step 2:
Freight Access Issue

- ☑ Describe current or anticipated issues
- ☑ Identify causal factors or key performance issues

[46] Seaford, Delaware. Seaford Industrial Park. http://www.seaforddde.com/index.cfm?ref=82100 Accessed 9 September 2015.

Because continued rail and barge service is susceptible to demand changes in the types and volumes of products shipped (as the local manufacturing base changes and evolves), as well as maintenance challenges, rail and barge service on the peninsula have been identified as a freight topics of concern within the Delmarva Freight Plan.[47] The U.S. Army Corps of Engineers recently dredged the Nanticoke from the Delaware-Maryland border to Seaford, bringing its depth to 12 feet (before this, the last time the river was dredged was in 1990).[48] However, the Delmarva Freight Plan has identified "ongoing concerns regarding inadequate dredge funding, a failure to secure sites for excess dredge materials, or delayed completion of channel maintenance." If sediment is allowed to build up again on the Nanticoke, Wicomico, or Pocomoke Rivers, barges will be forced to reduce their loads, thereby making other modes more attractive. The plan has also identified the Seaford Swing Bridge—a 100 year old rail bridge "with questionable track structure, electronics, and technology" crossing the Nanticoke River just south of Seaford—as an example risk factor emblematic of wider concerns regarding the future condition and availability of the rail network.[49] Again, if rail service were reduced or eliminated, these could lead to mode switching and an overall reduction in access to and from the manufacturing cluster's consumer and supplier markets, respectively.

WILMAPCO has also expressed concern regarding secondary effects in Seaford on the local street network: most truck shipments to and from Seaford travel approximately three miles east to U.S. Route 13—the peninsula's main north-south artery that provides access to East Coast metropolitan areas and other points north. State Route 20 provides a route for trucks leaving the Invista facility to reach Route 13. If—for lack of rail service or other reasons—congestion and delays increase along SR 20 as it passes through downtown Seaford, trucks may divert to local streets that cut through residential neighborhoods. This in turn would raise issues about impacts on the local community.[50]

The next section of this case study will focus on using Delmarva Freight Plan model outputs to examine potential risk factors related to multimodal freight access on the Delmarva Peninsula.

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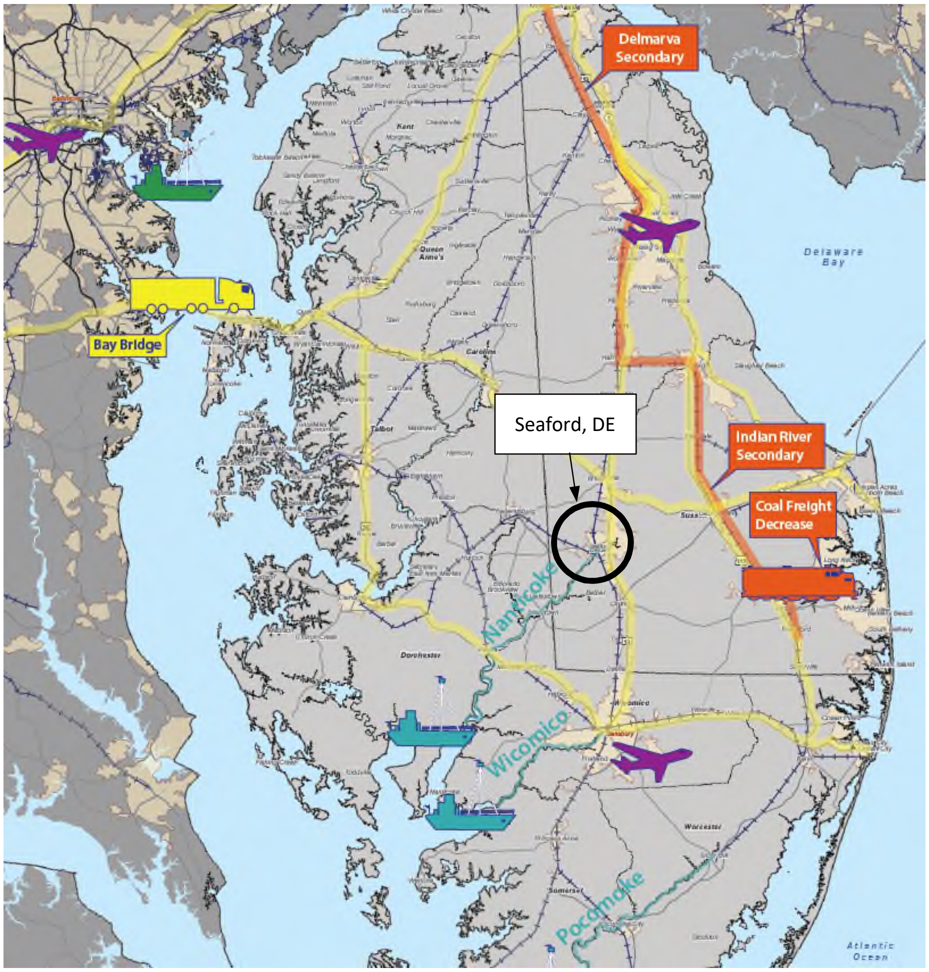
[47] Delmarva Freight Study: Project Status Update. December 2013. http://www.wilmapco.org/freight/Delmarva/Delmarva_Study.pdf, page 13. Accessed 10 June 2014.
[48] See https://www.sussexcountyde.gov/nanticoke-river-dredging-project.
[49] Delmarva Freight Plan. Final Draft Report March 2015. Page 136.
[50] Blevins, 2014.

Figure 9. Freight-Related Areas of Concern in Delaware



Source: Wilmington Area Planning Council, Delmarva Freight Study.

Freight Accessibility Measurement

This case addresses the interdependence of rail, barge, and truck accessibility. If the supply of rail or barge transportation options are reduced in the future, this change in service provision will decrease the freight accessibility of the manufacturing site both by reducing accessibility to different modal options, and through mode switching and congestion effects on truck accessibility.

Given concerns regarding the availability of rail and barge service, this case presents a need for comparisons of freight accessibility across modes and across alternate future scenarios.

Step 3:
Select Measurement Approach

- ☑ Consider prior analyses
- ☑ Select an appropriate comparative framework
- ☑ Identify available data and tools
- ☑ Choose an approach that matches the required level of detail for identified freight

Prior Analyses

As in the Port of Wilmington case study, this investigation of freight accessibility in Seaford, Delaware builds off modeling efforts recently completed as part of the Delmarva Freight Plan. Following the identification by regional stakeholders of rail and barge service as "areas of concern," the Freight Plan uses the Cube Cargo model to investigate the effects of peninsula-wide reductions in rail and barge access, with specific rail service constraints at Seaford and additional rail and barge constraints across the peninsula.

Selection of Metrics

To assess the importance of rail and barge service to freight accessibility in the Seaford area, this case study builds on data from two Delmarva Freight Plan scenarios: 2020 Trendline and 2040 Multimodal Constraint with Trendline Growth. The 2040 Trendline scenario serves a baseline against which to compare an alternative future with multimodal service constraints.

The 2040 Multimodal Constraint scenario addresses a number of "what-if" questions, including:

- What if the NS Delmarva Secondary became a shortline railroad from Porter (in Bear, Delaware) to Seaford?
- What if rail operations south of Seaford effectively ceased due to key infrastructure failures (e.g. Seaford rail bridge or BCRR car float)?
- What if Wicomico and Pocomoke River barge travel was restricted due to funding / dredging constraints?

It is important to note that this scenario was not constructed for the sake of analyzing freight access issues at Seaford, specifically, and therefore does not seek to isolate Seaford-specific accessibility risk factors. While the scenario does model rail constraints on the NS Delmarva Secondary, which passes through Seaford, it does not include any restrictions on the Nanticoke River. Aside from funding, one of the main drivers behind barge concerns is the availability of disposal sites for dredged materials. The Wicomico and Pocomoke Rivers did not at the time of the Delmarva Freight Plan's preparation have long-term solutions for dredge material disposal while the Nanticoke River did. The Multimodal Constraint scenario does, however, provide a set of model results regarding the movement of freight that help clarify the interdependence of accessibility across modes within the Delmarva Peninsula.

Using available model data, this case study compares freight accessibility across modes and between the baseline and alternate growth scenario, using a combination of infrastructure-based and area-based measures:

- Truck delay and speed on key facilities providing access to Seaford (infrastructure-based measures)

- Employment accessible from within various travel time thresholds of the Seaford manufacturing cluster, by different modes (an area-based activity access measure)

These metrics are selected to address underlying causes of freight accessibility issues (namely: roadway congestion from mode switching effects away from rail and barge service) and the likely economic implications of constrained modal availability and market reach for the manufacturing and freight-reliant businesses in Seaford, DE.

Implementation of Selected Metrics

Step 4:
Implement Measurement Approach

☑ Calculate selected metrics

☑ Describe relationship between metrics and identified issues

☑ Consider policy implications

Table 9 presents a set of infrastructure-based measures extracted from the Delmarva freight model, under the 2040 No-Build and the 2040 Multimodal Constraint scenario. These metrics summarize performance on the network in the area immediately around the Invista manufacturing site and thus address "last-mile" access changes between scenarios. Overall truck-hours and truck-miles traveled on the local street network increase between the scenarios, while the implied average speed decreases slightly. As was true for the Port of Wilmington case study, these changes are not drastic but do lend some credence to concerns over the pressure on the road network from mode switching in scenarios with less availability of rail and barge services. The results also highlight the limitations of general region-wide planning scenarios for addressing site-specific concerns.

Table 9 Infrastructure-based measures for a 5-mile radius area around the Invista Site

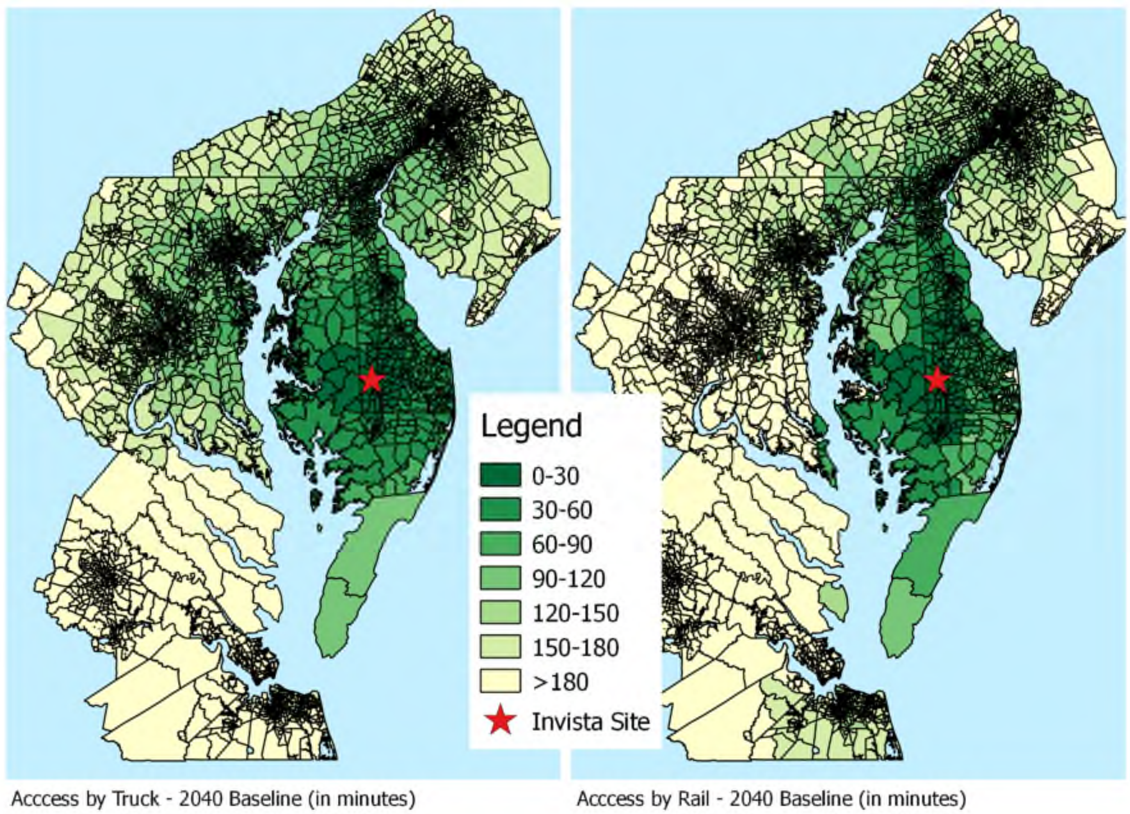
Measure	2040 No-Build	2040 Constraint	% Change from No-Build
Truck-hours traveled	2,488	2,538	2.03%
Truck-miles traveled	104,525	106,187	1.59%
Average Speed (Total VMT/VHT)	42.02	41.84	-0.43%

Source: EDR Group Analysis using QGIS and data from the Delmarva Cube Cargo model.

In addition to the secondary effects on the road network of mode switching, the direct effects on accessibility of removed modal options is also a concern for the Seaford area. As can be seen in Figure 10 and Table 10, accessibility from the Invista manufacturing site is forecast to be almost identical across rail and truck modes in the 2040 Trendline scenario. This relative equivalence of accessibility across modes offers a locational advantage for industries like Invista that are dependent on bulky commodities.

At present, modeled zone-to-zone travel times by mode under the 2040 Multimodal Constraint scenario are not available from the Delmarva freight planning efforts. However, if that additional information were available, an important next step in this analysis would be to perform the same computations of accessible employment under that alternate future, and then to compare changes between the two scenarios. Such an analysis would help to further quantify the risk associated with reductions in rail and barge service.

Figure 10 Accessibility of the Invista Site in Seaford, DE – mapping of areas accessible within incremental 30 minute travel time bands, by truck and by rail



Source: EDR Group Analysis using QGIS and data from the Delmarva Cube Cargo model.

Table 10 Employment Accessible within 180 minutes of the Invista Site

Measure	2040 No-Build Truck	2040 No-Build Rail	Ratio Rail:Truck
EMP 180 - Services	11,036,926	9,990,811	0.91
EMP 180 - Industry	1,054,096	1,043,340	0.99
EMP 180 - Total	**12,091,022**	**11,034,151**	**0.91**

Source: EDR Group Analysis using QGIS and data from the Delmarva Cube Cargo model.

4.3 Appalachian Region

This case study draws on a variety of material produced by and for the Appalachian Regional Commission (ARC) that assesses freight accessibility issues within the region and their economic development implications. While ARC has been responsible for a wide variety of infrastructure projects over the last half century, this narrative focuses specifically on how ARC's various transportation infrastructure initiatives have been targeted at addressing issues of accessibility and isolation. Unlike the other three case studies in this memo that present example analyses prepared in part or in whole by the consultant team, this case summarizes a set of existing analyses that showcase the use of network access measures to quantify county-level access to the national freight system.

Local and Regional Context

> ***Step 1:***
> ***Local & Regional Context***
> - ☑ Describe local and regional geography
> - ☑ Identify affected economic sectors
> - ☑ Identify relevant transportation infrastructure

The 205,000-square-mile Appalachian Region ("Appalachia") is comprised of 420 counties spanning from southern New York to northern Mississippi along the spine of the Appalachian Mountains. According to the Appalachian Regional Commission (the region's economic development agency established by an act of Congress in 1965), 42 percent of Appalachia's residents live in rural areas and just over 16 percent live in poverty (down from 33 percent in 1965). With the exception of metropolitan areas surrounding cities such as Pittsburgh, PA; Cincinnati, OH; Chattanooga and Knoxville, TN; Birmingham and Huntsville, AL; and Atlanta, GA; the region is largely isolated and remote, relative to the rest of the United States. This has created a long history of economic challenges, and of initiatives to address those challenges through access-oriented transportation infrastructure investment.

The Appalachian Region's economy has evolved significantly over time. Once highly dependent on extractive industries (especially coal and timber), agriculture, and heavy industry (e.g. chemicals); the region's economy has diversified to include more varied manufacturing (including automotive manufacturing), as well as additional professional and technical services.[51] Accompanying this transformation has been a necessary but sometimes rocky transition from domestic commerce to the larger international marketplace.

Changes in technologies and integration into the global supply chain require new types of freight access to maintain economic viability of the Appalachian Region. Access to the national backbone highway, rail, air, and marine transportation system are of particular importance. At the scale of this case study no single piece of infrastructure is individually of interest, but rather the performance of the entire network as a whole and its ability to provide access to regional, national, and—in particular—international markets.

[51] ARC. Appalachian Region. http://www.arc.gov/appalachian_region/TheAppalachianRegion.asp. Accessed 10 June 2014.

Freight Access Issues

Past Challenges and Solutions

When the ARC was first conceived of in 1964, the commission appointed by President Johnson to explore the concept of a regional organization reported to Congress that "economic growth in Appalachia would not be possible until the Region's isolation had been overcome."[52] This statement was made with the recognition that the Interstate Highway System had "largely bypassed the Appalachian Region, going through or around the Region's rugged terrain as cost effectively as possible."[53] It was a strong and early acknowledgement of the relationship between accessibility and economic opportunity.

> ***Step 2:***
> ***Freight Access Issue***
>
> ☑ Describe current or anticipated issues
>
> ☑ Identify causal factors or key performance issues

Ongoing efforts to address freight access issues in Appalachia have been motivated by a high-level understanding of the relationship between global market opportunities and economic advantage. Development of the Heartland Corridor double-stack rail line, for instance, was inspired in part by an ARC-funded transportation study of a 13-county region in the southwest corner of West Virginia that was characterized as "both physically and economically isolated."[54] The Heartland Corridor project became a way of addressing the economic disadvantage of inadequate intermodal access in Central Appalachia, while tapping into the market opportunities provided by the Port of Virginia in Hampton Roads and the "midwestern industrial heartland".[55]

Freight access throughout Appalachia has improved significantly since passage of the Appalachian Regional Development Act of 1965, the bill that established ARC and the Appalachian Development Highway System (ADHS). The ADHS, which was 89 percent complete or under construction as of 2014, is a 3,090-mile highway system[56] designed to:

(1) Link Appalachia to key external markets;

(2) Enhance the flow of commerce, opening isolated areas to economic opportunity; &

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[52] ARC. Status of the Appalachian Local Access Road Program. September 2012. http://www.arc.gov/images/programs/transp/StatusofAppalachianLocalAccessRoadProgramFY2011.pdf, page 1. Accessed 10 June 2014.

[53] ARC. Status of the Appalachian Local Access Road Program. September 2012.

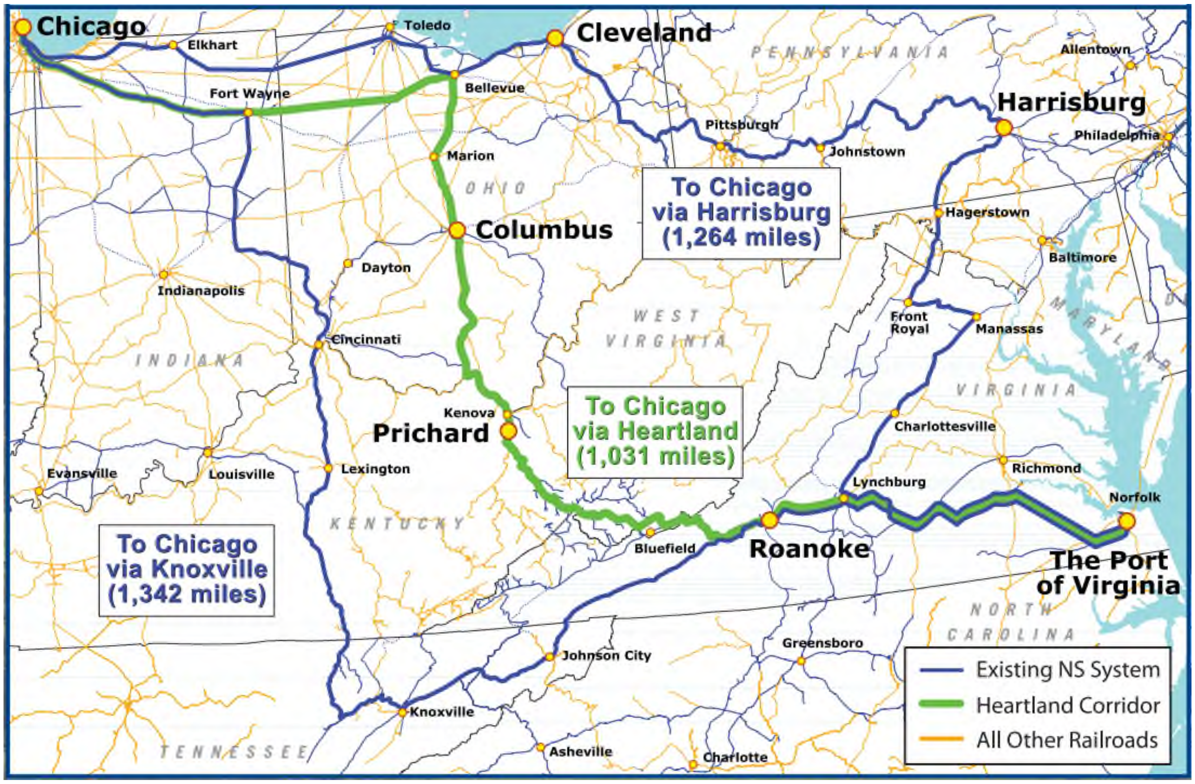
[54] Appalachian Transportation Institute and the Center for Business and Economic Research, Marshall University. Transportation and the Potential for Intermodal Efficiency-Enhancements in Western West Virginia: Final Phase I Report. May 2000.

[55] ARC. The Heartland Corridor: Opening New Access to Global Opportunity. http://www.arc.gov/images/programs/transp/intermodal/HeartlandCorridor.pdf Accessed 10 June 2014.

[56] Center for Regional Economic Competitiveness and West Virginia University. Appalachia Then and Now: Examining Changes to the Appalachian Region since 1965. February 2015. http://www.arc.gov/assets/research_reports/AppalachiaThenAndNowCompiledReports.pdf

(3) Facilitate commutation to work and delivery of key social services to residents.[57]

Figure 11. The Heartland Corridor



Source: ARC. The Heartland Corridor: Opening New Access to Global Opportunity

In addition to funding the ADHS, the ARC road building efforts also include a Local Access Road (LAR) program. The program "aims to better link the Region's businesses, communities, and residents to the Appalachian Development Highway System and to other key parts of the Region's transportation network" (see Figure 12).[58] To supplement the ADHS network, the LAR program focuses on "last mile" connections between specific business locations (e.g. individual industrial user sites or multi-user industrial parks) and the highway system in Appalachia, as well as local connector roads.[59] Evaluations have

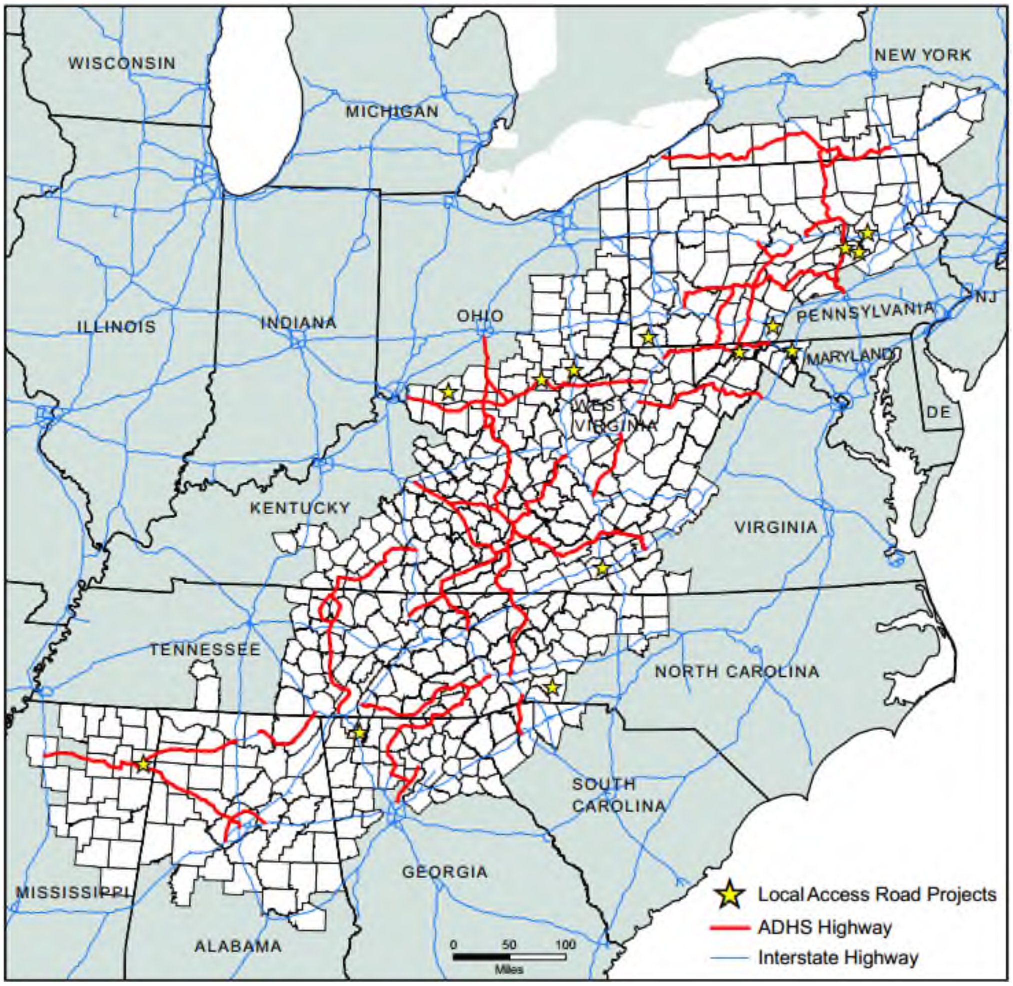
[57] ARC and Moffatt & Nichol. Network Appalachia: Access to Global Opportunity. 2010. http://www.arc.gov/images/programs/transp/intermodal/NetworkAppalachiaAccesstoGlobalOpportunity.pdf, page. Accessed April 2011.

[58] ARC. Access Road Program. http://www.arc.gov/program_areas/AccessRoadProgram.asp. Accessed 11 June 2014.

[59] The Brandow Company and Economic Development Research Group. Evaluation of the Appalachian Regional Commission's Infrastructure and Public Works Program Projects. 2000. http://www.arc.gov/assets/research_reports/EvaluationofARCsInfrastructureandPublicWorksProgramProjects3.pdf Accessed 11 June 2014.

demonstrated the positive economic impacts of access road projects and, as of 2011, a total of 974 road miles had been approved (using ADHS funds) throughout the 13-state region.[60]

Figure 12. Local Access Road Projects in Appalachia, FY 2011



Source: ARC. Status of the Appalachian Local Access Road Program. 2011.

Remaining Challenges: Freight and Intermodal Accessibility

Despite progress made by the ADHS, economic development benefits deriving from the highway system in an increasingly globalized economy are limited by a lack of connectivity to coastal ports and intermodal terminals. A 1999 study commissioned by ARC found that "While ADHS has served as the centerpiece of ARC's economic development program, highways alone are no longer sufficient to help Appalachia's communities compete in the

[60] ARC. Status of the Appalachian Local Access Road Program. 2011. http://www.arc.gov/images/programs/transp/StatusofAppalachianLocalAccessRoadProgramFY2011.pdf, pages 2-3. Accessed 11 June 2014.

global marketplace."[61] In recent years, therefore, ARC has honed its access-oriented approach to specifically address issues related to freight and intermodal accessibility, at a broader corridor and system-level. Inadequate intermodal access, ARC argues, results in higher shipping costs and competitive disadvantage for business in Appalachia. ARC recommends integrating the ADHS with intermodal corridors and developing inland ports to better connect isolated communities with domestic and global markets.[62] As part of the study leading up to this recommendation, the research team conducted a comprehensive region-wide accessibility analysis, which is discussed in the following section.

Freight Accessibility Measurement

This case study differs from the others in that it summarizes a set of completed analyses used by ARC to document and communicate the freight accessibility issues confronted by the region.

Selection of Metrics

Based on the remaining freight and intermodal accessibility challenges described above, ARC adopted a specific set of metrics designed to quantify the extent of freight "transportation connectivity…to the global marketplace." [63]

The selected measurement approach was designed to (a) identifying counties where transportation enhancements could support global competitiveness of local businesses that are import or export related, and (b) facilitate and support regional discussions and future collaborative planning efforts across the region. To address these requirements, the approach involves a county-level comparison of current accessibility with a set of metrics that are then weighted based on stakeholder priorities and combined into a single composite score.

Step 3:
Select Measurement Approach

- ☑ Consider prior analyses
- ☑ Select an appropriate comparative framework
- ☑ Identify available data and tools
- ☑ Choose an approach that matches the required level of detail for identified freight access issues.

The accessibility issues of interest cover a broad multi-state region and multiple modes. As a regional economic development agency, ARC needed to systematically analyze the relative levels of accessibility across its constituent areas, as a way of establishing a defensible baseline understanding of the accessibility constraints faced by locations within the region. For this reason, the measurement approach was designed to be replicable across a large set

[61] ARC and Smith (Wilbur) and Associates. An Assessment of Intermodal Transportation Plans, Systems, and Activities in Appalachia. 1999.
[62] ARC. Network Appalachia: Planning Global Access to Economic Growth and Opportunity. (Handout fact sheet), April 2011.
[63] ARC and Moffatt & Nichol. Network Appalachia: Access to Global Opportunity. 2010.

of zones and based on relatively simple procedures that can be automated. Rather than analyzing specific locations or freight-generating activities based on local knowledge, the ARC measurement approach was built using existing GIS data sets for ease and consistency of implementation.

Table 11 summarizes the selected measurement approach used by ARC using the taxonomy established in Chapter 2. The adopted measures are area-based network access measures that quantify access to key nodes in the national freight system.

Implementation of Selected Metrics

Step 4:
Implement Measurement Approach

- ☑ Calculate selected metrics
- ☑ Describe relationship between metrics and identified issues
- ☑ Consider policy implications

The selected metrics were implemented in a two-step process. First, distances were calculated to each type of transportation network destination for all counties in the region. Second, a normalization and weighting scheme was applied to yield a single composite score for each county.

To be able to compare the different types of access, the distance calculations were normalized across proximity measures so that for every type of opportunity a value of 0 represents the minimum level of access measured across Appalachia and a value of 1 corresponds to the maximum value of access measured. This converts each proximity measure to an indicator of relative access across the entire ARC region, even if the distances involved vary considerably (e.g. on average an ADHS/National highway will be much closer to any given point than a coastal port will be).

Subsequently, the research team applied a set of priority weightings to combine the different access measures into a single score, based on stakeholder priorities (as in a multi-criteria analysis). For example, the research team measured access to both intermodal rail terminals and local/regional rail (non-container) terminals, but weighted the prior more heavily than the latter. Similarly, access was measured to both Interstates and the ADHS, but the Interstate access was weighted more heavily in the development of final accessibility scores for each county. This approach accounts for the fact that there is a hierarchy of accessibility provided by different levels of infrastructure within the overall transportation network of a region.

The final results of the analysis were summarized in a single map in with three classes of counties: green colored counties denote strong access, yellow colored counties denote medium levels of accessibility, and grey colored counties indicate counties with low levels of access (see Figure 13).

Table 11 Selected Freight Access Measurement Approach: Appalachia

Network Access Measurement in Appalachia

1 User Group — Access for whom/from where?

- Access throughout the ARC region was measure at the **county-level**. The geographic **centroid** of each county was selected as the origin point for calculations.
- A simple geographic centroid was selected in order **to keep calculation methodologies uniform** across a broad region.
- The ARC research team acknowledged the potential bias of not using other selection criteria to identify origin points that most closely approximate business locations within a county, but opted for the simplified more readily reproducible approach.

2 Attractions/ Destinations — Access to where/what?

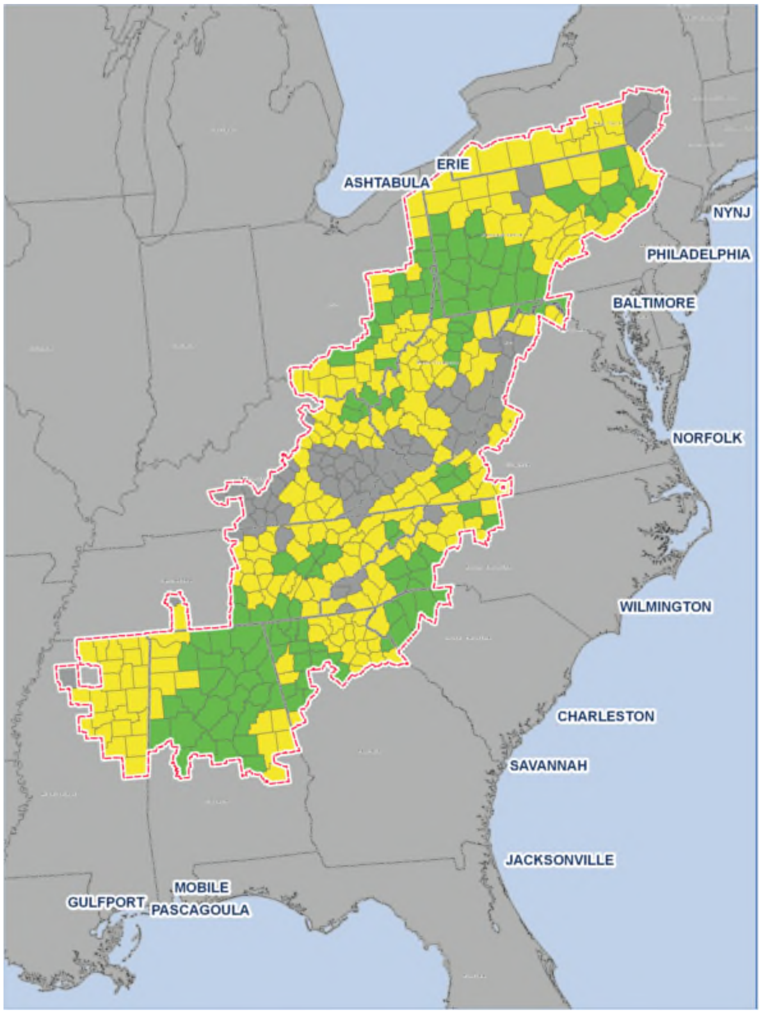
- The study includes a set of **network access** measures that measure proximity to **transportation links and nodes:**

Attraction/Destination	Freight Accessibility Importance within ARC
Interstate highway (entry/exit ramps)	Serve as primary links to global gateways such as ocean/river ports or Intermodal Container Transfer Facilities (ICTFs).
ADHS/national highway (links)	Routes that connect to the interstate.
Intermodal (Container) Rail Terminals (ICTF terminals)	Class I terminals with international intermodal services between ocean ports and ICTFs.
Multimodal Rail Terminals (non-container terminals)	Point of access for short line railroads and Class I railroads that are not intermodal routes but nevertheless provide important rail freight service.
Inland Waterway Port	Point of access for the navigable river system.
Intermodal-Interstate Intersection	Locations with developable land close to an intermodal rail line and an interstate highway, targeted as locations with logistics-related development opportunities
Coastal Ports	Major gateways to global trade.

3 Impedance — Access at what cost and along which network?

Impedance quantification:	distance
Network definition:	truck routing software
Functional form of cost:	distance to closest opportunity

Figure 13 Access Evaluation Map: Appalachia



Source: ARC and Moffatt & Nichol. Network Appalachia: Access to Global Opportunity. 2010.

The results of the accessibility analysis were used as inputs to a much broader engagement process across the region with planners and economic development officials, modal operators, universities, and business representatives. Through a series of workshops, the analysis, along with expert input from stakeholders, was translated into a set of strategic priorities and specific tactical (near- and medium-term) opportunities for improving access to domestic and international markets. These proposed projects included inland ports, highway corridor improvements, rail improvements, and a maritime shuttle.

In summary, this case represents the type of use case in which an agency will prefer to select relatively simple freight accessibility measures that can be applied uniformly across a large region, in a consistent manner. And while the overall approach is not computationally intensive, the use of multiple metrics and a weighting scheme nevertheless enables the analyst to create a nuanced picture of accessibility across Appalachia—a picture that can be directly and simply communicated as part of a broader planning process.

4.4 North State Super Region (California)

Like the Appalachia case study in the previous section, this case study addresses access issues on a regional scale. As was the case in Appalachia, terrain and network coverage are major sources of access constraints in the North State. The case study analysis employs both infrastructure-based and area-based accessibility metrics to address terrain-, remoteness-, and infrastructure-related constraints that limit economic development in the North State super region of California.

Local and Regional Context

Step 1:
Local & Regional Context

- ☑ Describe local and regional geography
- ☑ Identify affected economic sectors
- ☑ Identify relevant transportation infrastructure

The North State Super Region is comprised of 16 counties covering 42,620 square miles from Sacramento's northern exurbs to California's borders with Oregon and Nevada.[64] Generally speaking, the region is split among a coastal area, a mountainous area, and the agriculturally-oriented Sacramento Valley—each of which is largely rural and reliant on resource-based industries. A single north-south Interstate (I-5) traverses the Sacramento Valley, and the coast and mountains are served by U.S. Route 101 and Route 395, respectively. Between these major routes are many areas isolated by mountains and long, circuitous state highways that see little interregional traffic (see Figure 14).[65]

Relative to California, the North State economy shows several signs of distress: In 2012, the unemployment rate in the North State was approximately 12.5 percent, compared with 11 percent in California. Labor force participation is also low, with county rates between 40 and 60 percent. The weak economy has contributed to high levels of poverty in the region; some counties have over 20 percent of households below the poverty line (as of 2010).[66]

[64] The North State is comprised of Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Nevada, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity counties.

[65] System Metrics Group et al. North State Transportation for Economic Development Study (NSTEDS): Full Compendium Report. 2013. http://www.srta.ca.gov/pastel/NSTEDS%20Final%20Report%20for%20Web-posting%20TAC_100913.pdf. Accessed 12 June 2014.

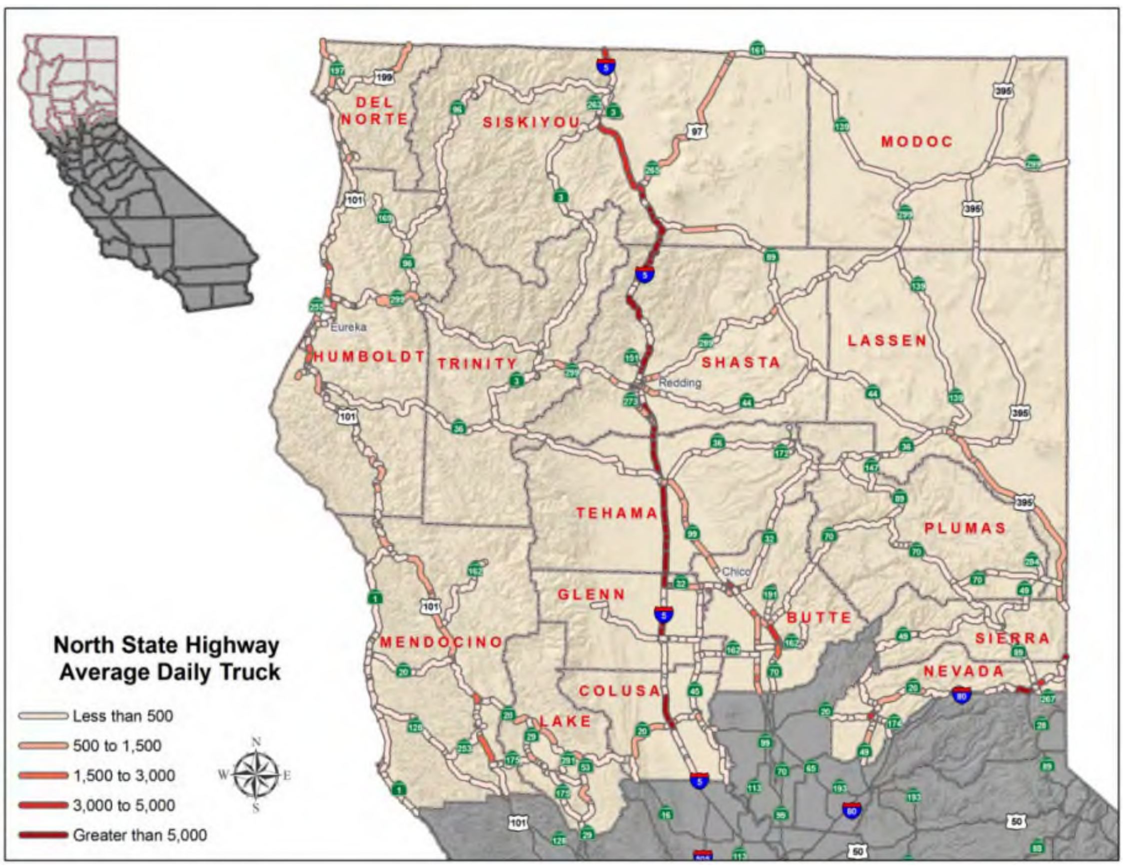
[66] NSTEDS, pages J35-36.

Freight Access Issues

> ***Step 2:***
> ***Freight Access Issue***
>
> ☑ Describe current or anticipated issues
>
> ☑ Identify causal factors or key performance issues

Freight access throughout the North State is limited by remoteness; poor connectivity to industry inputs, ports, and intermodal facilities; and circuity caused by challenging terrain, weather, and seismic activity (see Figure 15). Physical design characteristics constraining truck travel, in particular, include narrow roads, sharp turns, weight restrictions, and an absence of passing lanes. Because many areas of the North State are served by only a single highway, the region's economic activity is also vulnerable to emergency closures that leave trucks with few alternative routes.[67] Access to freight intermodal facilties including rail terminals and airports is also limited.

Figure 14. Truck Traffic on North State Highways



Source: System Metrics Group et al. North State Transportation for Economic Development Study. 2013.

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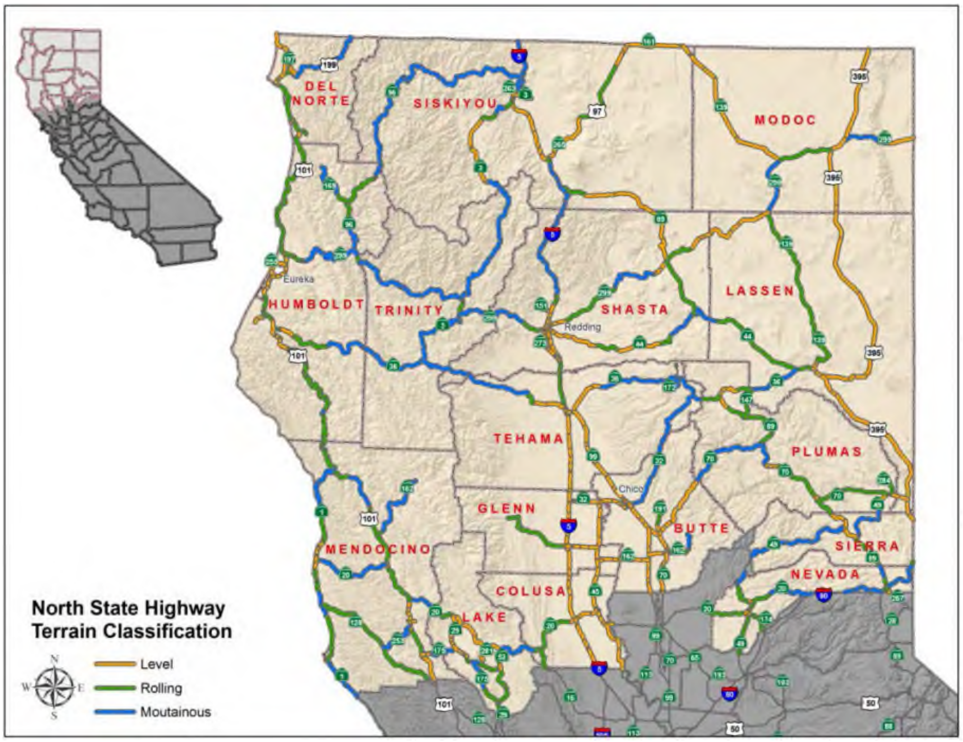
[67] NSTEDS, page xiv.

In 2012, the Shasta County Regional Transportation Planning Agency (Shasta County's MPO) commissioned a study of the relationship between transportation and economic development in the North State. Among other aims, the study sought to "Identify major accessibility-related obstacles and opportunities to economic activity" in the region.[68]

Figure 15. Terrain Conditions on North State Highways



Source: System Metrics Group et al. North State Transportation for Economic Development Study. 2013.

According to the study, every available freight mode in the North State faces limitations that directly or indirectly impact economic activity in the region:[69]

- There are few highway options for east-west travel and none have more than two lanes. Moreover, many existing sections of highway face access limitations due to design or topography.
- While two Class I railroads serve the Sacramento Valley and the eastern half of the state, the North Coast area has been without freight rail service for more than a decade.

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[68] Shasta County Regional Transportation Planning Agency. North State Transportation for Economic Development Study Request for Proposals. 2012.
[69] See NSTEDS, page v.

- In contrast to neighboring regions, the North State has no commercial hub airports or rail intermodal loading facilities.

Freight Accessibility Measurement

Prior Analyses

> ***Step 3:***
> ***Select Measurement Approach***
>
> ☑ Consider prior analyses
>
> ☑ Select an appropriate comparative framework
>
> ☑ Identify available data and tools
>
> ☑ Choose an approach that matches the required level of detail for identified freight access issues.

The 2012 North State study implemented a number of access-related metrics capturing limitations related to both passenger and freight accessibility. These included:

- Same-Day Truck Delivery Market: Employment within a 3-hour drive time of each county centroid.
- International Air Freight Gateway Access: drive time to the nearest major commercial airport.
- Rail Intermodal Facility Access: drive time to the nearest rail intermodal loading facility.

The project team used the selected metric to establish a consistent baseline of accessibility across the region and to assess the potential gains from addressing identified terrain and infrastructure-related truck access constraints. For example, in the case of the Same-Day Truck Delivery Market, the research team first evaluated the metric for each county in the region. After establishing an initial baseline, the North State research team then used sketch-level planning methods to estimate the changes in accessible market areas from proposed truck access projects. The change in the accessible area was based on the assumption that changes in accessibility will be "commensurate" with estimated speed improvements from the truck access projects analyzed. The change in accessibility to consumer and supplier markets was then used as an input to economic modeling, which estimated business productivity improvements derived from agglomeration and economies of scale.[70] This is an example of how accessibility measures can be used to track progress or evaluate projects, even at a sketch-level of planning.

Selection of Metrics

As highlighted above, prior analyses have been used to document and communicate the potential for accessibility improvements, based on a set of sketch-level projects targeted specifically at improving truck access in the North State.

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[70] NSTEDS, 123.

Given the nature of the access issues discussed above, another goal that can be met by accessibility analysis is to document and quantify the relative isolation of the North State region. To this end, this case study compares accessibility in Humboldt County, located along the coast in the North State, to accessibility in Monterey County, another coastal county in the central portion of the state used as a reference. The comparative assessment uses standardized replicable procedures that can be applied generically across zones (in this case, counties). Thus while the case only performs the analysis for one North State county, the approach could be easily replicated.

In addition, this case study employs a variety of freight access metrics, to address the multiple dimensions of identified freight access constraints, including: limitations in freight network coverage, limitations in access to intermodal facilities, and limitations in the scale of the accessible market. The objective is not to select a single comprehensive metric, but rather to employ a suite of easily-calculated measures to establish the relative disadvantage of North State counties, as compared to other counties in the State.

Metrics are calculated using spatial network data maintained by the California Department of Transportation (Caltrans),[71] roadway travel time data from ESRI, employment data from InfoGroup accessed through ESRI Business Analyst Online, airport and rail terminal data from Caltrans,[72] and spatial analysis tools embedded in a number of commonly used GIS packages (ESRI and QGIS[73]). These data sources and tools are representative of the types available to a State DOT or MPO—although specific network and activity data sources may vary.

The selected freight access measures are summarized in Table 12. The metrics are described according to the framework established in the Chapter 2 and include:

- **Network coverage measures** that quantify the density of available transportation networks (truck and rail).
- **Area-based activity access measures** that quantify the scale of business activity (as proxied by the number of employees) accessible within a one-day drive time threshold of each county. These measures are applied for both total employment, and for subsectors that may be of particular relevance to the resource-based industries in the North State.
- **Area-Based network access measures** that quantify access to key nodes in the national freight system, weighted by indicators of the level of activity at those nodes (air cargo tonnage for airports and yard lift capacity for rail intermodal facilities).

[71] California Department of Transportation. Caltrans GIS Data. http://www.dot.ca.gov/hq/tsip/gis/datalibrary/
[72] California Department of Transportation. California Aviation System Plan: 2013 Inventory Element. http://www.dot.ca.gov/hq/planning/aeronaut/documents/casp/casp_inventory_element_20130919.pdf and 2013 California State Rail Plan. Table 6.5: Intermodal Rail Facility Characteristics. http://californiastaterailplan.dot.ca.gov/docs/Final_Copy_2013_CSRP.pdf
[73] QGIS is a free and open source Geographic Information System. See: http://www.qgis.org/en/site/

Table 12 Selected Freight Access Metrics: North State Comparative Analysis

Metric	Origin Point	Attraction / Destination	Data Sources	Analysis Tool
NETWORK COVERAGE MEASURES				
Miles of Truck network within a 100 mile radius	Centroid	N/A	Caltrans GIS Data: Truck Network (2011)	QGIS
Miles of Rail network within a 100 mile radius	Centroid	N/A	Caltrans GIS Data: California Rail Network	QGIS
AREA-BASED ACTIVITY ACCESS MEASURES				
Total employment within a 180 minute drive time area	Centroid	Employment	ESRI drive times; InfoGroup industry data	ESRI Business Analyst Online
Transportation & Warehousing employment within a 180 minute drive time area	Centroid	Transportation & Warehousing Employment	ESRI drive times; InfoGroup industry data	ESRI Business Analyst Online
Manufacturing employment within a 180 minute drive time area	Centroid	Manufacturing Employment	ESRI drive times; InfoGroup industry data	ESRI Business Analyst Online
AREA-BASED NETWORK ACCESS MEASURES				
For the closest NPIAS primary commercial service airport[74] with recorded air cargo in 2013: (Air cargo tonnage) / (Drive time to airport)	Centroid	Arcata Airport	ESRI drive times; Caltrans GIS Data: Public Use Airports (2015); CA Aviation System Plan 2013 (air cargo tonnage)	ESRI ArcGIS Online
		San Luis Obispo County Regional Airport		
For the closest rail intermodal facility: (Yard Lift Capacity) / (Drive time to intermodal rail facility)	Centroid	Oakland BNF & Railport UP (Near-Dock)	ESRI drive times; Caltrans GIS Data: California Freight Intermodal; 2013 CA State Rail Plan (Yard Capacity)	ESRI ArcGIS Online
		Oakland BNF & Railport UP (Near-Dock)		

Implementation of Selected Measurement Approach

Step 4:
Implement Measurement Approach

☑ Calculate selected metrics

☑ Describe relationship between metrics and identified issues

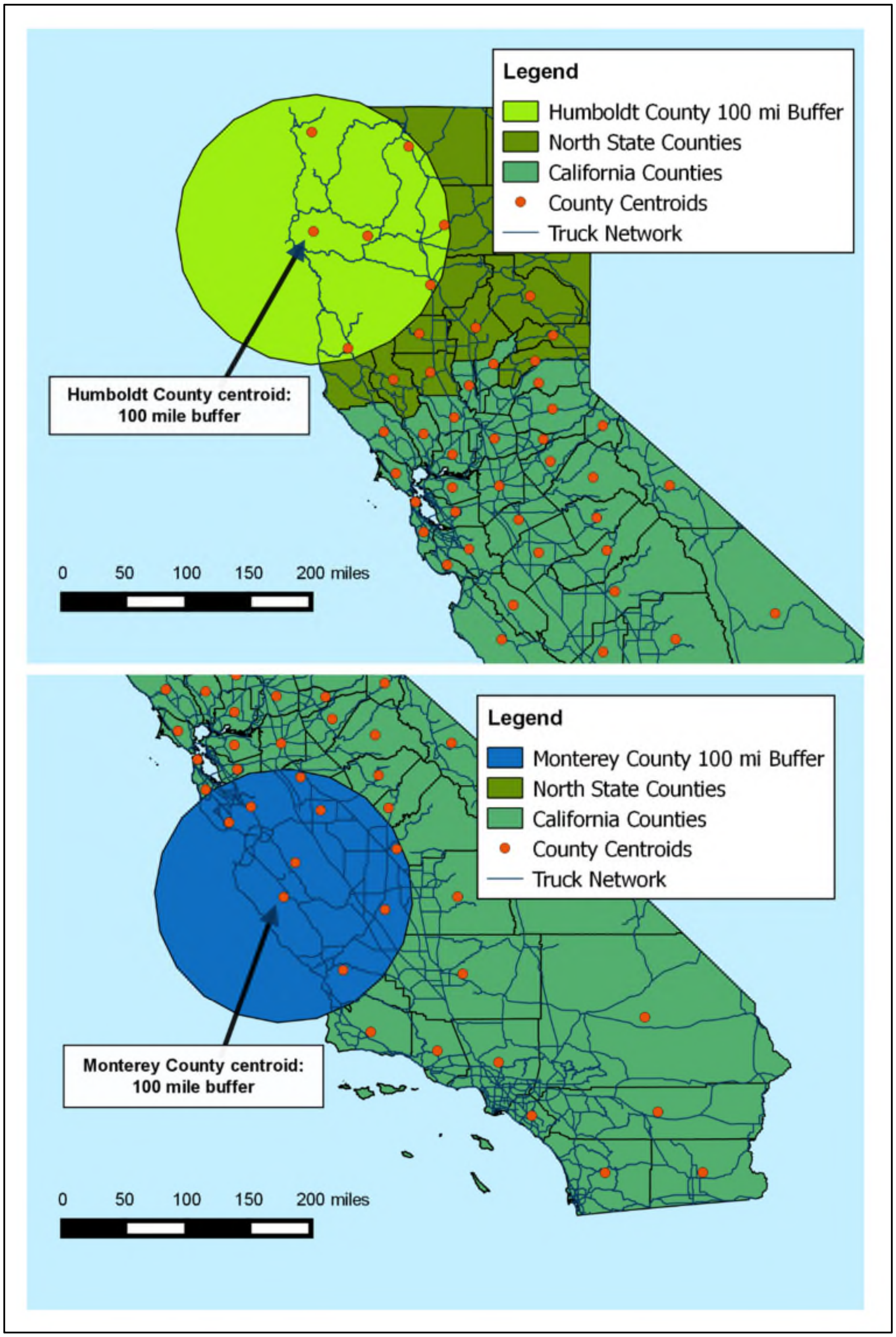
☑ Consider policy implications

The measurement approach outlined above was implemented in a Geographic Information System, yielding the results in Table 13. Figure 16 shows the spatial data used in the calculation of the truck network coverage measure. Figure 17 and Figure 18 show the drive time areas used for the area-based activity access measures. As can be seen in the figures, the shape and size of the accessible area is determined by the availability and quality of the region's highway infrastructure. The area-

[74] The National Plan of Integrated Airport Systems (NPIAS), prepared by the Federal Aviation Administration every 2 years, defines a system of airports considered significant to national air transportation in the U.S. Primary airports are public airports with scheduled air carrier service and 10,000 or more enplanements annually. (See: http://www.faa.gov/airports/planning_capacity/npias/)

based network access measures were calculated using simple point-to-point drive times from ESRI and intermodal facility characteristics as published by Caltrans.

Figure 16 Truck Network Density Calculations: North State Comparative Analysis

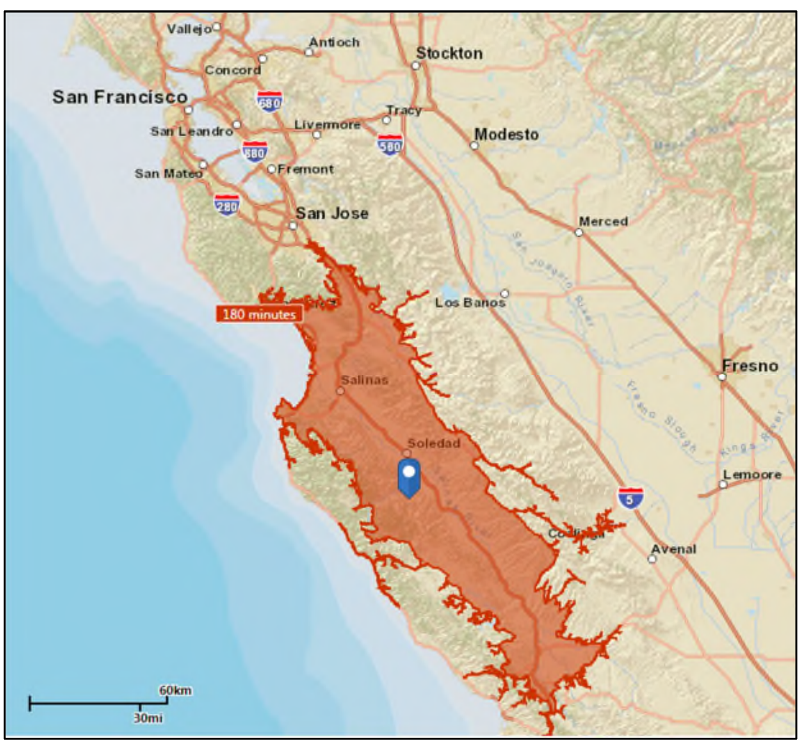


Source: EDR Group Analysis using QGIS

Figure 17 Humboldt County 180 Minute Drive Time Area

Source: EDR Group Analysis using ESRI Business Analyst Online

Figure 18 Monterey County 180 Minute Drive Time Area



Source: EDR Group Analysis using ESRI Business Analyst Online

Table 13 **Freight Access Analysis Results: *North State Comparative Analysis***

Metric	Area (County)	Value	Units	Ratio (Humboldt / Monterrey)
NETWORK COVERAGE MEASURES				
Miles of Truck network within 100 mile radius	Humboldt	1,266	miles	***0.59***
	Monterey	2,157		
Miles of Rail network within 100 mile radius	Humboldt	406	miles	***0.50***
	Monterey	819		
AREA-BASED ACTIVITY ACCESS MEASURES				
Total employment within 180 minute drive time	Humboldt	75,832	Employees	***0.19***
	Monterey	395,043		
Transportation & Warehousing employment within 180 minute drive time	Humboldt	1,804	Employees	***0.22***
	Monterey	8,110		
Manufacturing employment within 180 minute drive time	Humboldt	2,862	Employees	***0.11***
	Monterrey	25,583		
AREA-BASED NETWORK ACCESS MEASURES				
For the closest NPIAS primary commercial airport with recorded air cargo in 2013: (Air cargo tonnage) / (Drive time to airport)	Humboldt	(343 tons) / (52.02 minutes) = 6.59	tons/minutes	***0.82***
	Monterey	(908 tons) / (112.72 minutes) = 8.06		
For the closest rail intermodal facility: (Yard Lift Capacity) / (Drive time to intermodal rail facility)	Humboldt	(600,000 lifts) / (346.43 minutes) = 1,732	tons/minutes	***0.50***
	Monterey	(600,000 lifts) / (174.45 minutes) = 3,439		

As shown Table 13, Humboldt County in the North State is between 10% and 60% as accessible as Monterey County, depending on the chosen freight accessibility metric. Thus, the measures confirm the perceived relative disadvantage of this county in the North State, compared to another reference county in California. The worst performance is found in the area-based activity access measures, followed by the measures related to rail service. The activity access measures (access to employment) reflect the joint influence of roadway network characteristics and the distribution of economic activity in geographic space. Because the North State is both remote and relatively less densely settled, overall access to employment within a 3-hr drive of the centroid of Humboldt County is significantly less than in an equivalent drive time market area for Monterey County. This highlights the challenges faced by remote regions in overcoming distance, even in cases with adequate transportation infrastructure.

Overall, this case demonstrates the utility of using different types of measures side-by-side to develop a more complete story about the extent of the accessibility issue, and its underlying causes: Employment within a three hour driving radius is a measure of the effective size and breadth of the market accessible from the North State and thus a critical indicator for economic development potential. The network coverage measures, on the other hand, do not directly measure opportunities for economic engagement, but do provide a sense of limitations in the extent of the provided transportation network. Additionally, the network access measures for rail and air cargo facilities provide an additional modal dimension not captured by drive-times alone.

5 CONCLUSIONS AND FUTURE WORK

5.1 Case Study Implications

The case studies in Chapter 4 cover a range of freight access issues and contexts, addressing different:

- Regional development settings - e.g. urban, small community, and rural areas;
- Scales of analysis – e.g. local "last mile" accessibility for a specific site versus large-scale regional access to the national freight system;
- Sources of accessibility constraints – e.g. inadequate network coverage or connectivity, congestion, regulatory constraints, inadequate service levels, etc.; and
- Modes.

While the case studies highlight the multi-dimensionality of freight accessibility, they share some common themes and insights:

Freight accessibility is consistently viewed by practitioners and stakeholders as an important concern affecting the economic growth and development of regions and freight-generating activity centers. The cases demonstrate how accessibility concerns can be triggered by situations where an existing base of economic activity that had formerly been stable and viable starts to face the threat of becoming unsustainable and unviable because of one of two reasons:

1) *Certain factors threaten to negatively affect the capacity, cost or performance of existing freight access corridors.* In the Port of Wilmington case, surrounding land use and development changes threaten to create a bottleneck for current access corridors. In the Seaford, DE case, a decline in conditions and services affecting one mode of access threatens to overwhelm the capacity of remaining access modes and routes. In both cases, the result is a bottleneck for the remaining access routes and services that will reduce effective throughput or raise travel time and cost, and potentially make businesses relying on that access route less productive (and hence less economically competitive).
2) *Changes in technologies and markets are shifting the economy and requiring new types of freight access to maintain the economic viability of a region.* In the Appalachian Region and North State, CA cases, broader economic conditions have changed over time so that residents of a region can no longer rely on the same local resource-based industries and markets to generate their income. Yet, the region's economy cannot viably serve broader markets until there are better connections to wider freight networks. In these cases, deficiencies are in access to national

backbone highway and rail networks, or in access to major air/marine/intermodal terminals.

Once an issue has been brought forward, the cases also illustrate how freight accessibility can always be described in terms of:

- The needs of a specific location, user group, or constituency;
- Concerns about the ability to reach buyer and/or supplier markets (freight origins and destinations) via available transportation facilities and services; and
- Recognition that insufficient infrastructure raises the time and cost (impedance) of freight movement, which can limit the effective market size or revenue potential for affected businesses.

Overall, the cases validate the premise that accessibility concerns can be quantified and explained using a set of measures implemented within a systematic process. Moreover, the cases show how that process is less about selecting "the perfect metric" and more about designing an approach that captures the issues of concern, is implementable with available data and analytical resources, and will provide policy guidance at the appropriate level of detail. While there is no one-size-fits-all approach, the steps presented in Chapter 3 will guide agencies and analysts to a manageable and instructive process.

Finally, the cases do re-emphasize the fact that full portrayal of a freight accessibility issue requires both the more traditional infrastructure-based or network measures that addresses the underlying causes of accessibility constraints, and area-based measures that capture the scope of the problem within a given comparative framework (across space, time, scenarios, or investment proposals). The second type of measure has not been as full implemented within transportation agency business-processes but is necessary in order to measure the effective size and breadth of markets—and therefore the potential for economic participation.

5.2 Recommendations for Practice

The findings of this research indicate the following set of recommendations for freight transportation planning:

Recommendation 1. Planners and analysts should recognize freight accessibility as a transportation system performance measure. It should have a role in performance-based planning as a fundamental indicator of economic competitiveness.

Recommendation 2. Freight accessibility and its importance for economic development are not adequately captured by facility performance measures alone. The measurement, tracking, and analysis of freight accessibility should address the performance of key links and nodes in the freight network *in relation to* the needs of freight generators and the markets they wish to access. This can be accomplished through some combination of *infrastructure-based* and *area-based* freight accessibility measures.

Recommendation 3. As demonstrated by the case studies, freight accessibility measurement is currently possible and within reach for State DOTs and MPOs using the types of data and tools that are generally available inside agencies. As such, agencies should move to integrate more formal measurement of freight accessibility into existing agency business process. While there will be continuing advancements in methodologies and available tools, there is sufficient information for these measures to be useful now.

5.3 Future Research

This white paper focuses on presently available approaches to measuring freight accessibility. In researching and outlining the approaches, however, a number of topics were be identified as those that would benefit from future research and innovation—to support continued improvements in methodology, beyond those immediately implementable. These include:

- Continued development of a approaches and data sets for multi-state or national-level analysis of accessibility across modes;
- Further investigation into the behavioral basis for selecting travel time (and/or cost) thresholds in area-based accessibility measures;
- Design of industry-specific freight accessibility measures, using available data on freight flows and spatial supply-chains relationships;
- Methodologies for incorporating reliability (which is of critical importance in the freight world) into accessibility measurement approaches;
- Research into industry-specific productivity gains from improvements in freight accessibility, as measured by various accessibility metrics.

The authors hope that this white paper provides a platform from which to push both the state of practice and the state of research forward.

APPENDIX

Table 14 Examples of freight accessibility's inclusion in long-range planning

Freight access in planning	Examples
Goal Setting And Priority Definition	• Washington State's Freight Mobility Plan: describes the role of the transportation network as follows: to "provide access to markets, create jobs and economic growth, and link business, government, and economic activities together locally, nationally, and internationally.[75] • Montana's Long Range Transportation Plan: includes a policy goal to "preserve the efficient functioning of the transportation system used by Montana's export-oriented ("basic") industries to access regional, national, and international markets."[76] • Boston's Metropolitan Area Planning Council 30-year plan: includes "Expanding access to the global marketplace through efficient freight transportation" within its list of transportation goals.[77] • Virginia's Multimodal Freight Plan: defines "mobility, connectivity, and accessibility" as a goal and places investment priority on projects that improve the availability of multiple modal options (rail, water), reduce congestion and bottlenecks on key freight corridors, and improve last mile connections to Virginia's Corridors of Statewide Significance (CoSS) and to key freight centers; also explicitly connects freight accessibility/ connectivity with the ability of the state to export its goods, with the goal to "Strengthen connections between international trade gateways and manufacturing, distribution, retail centers, and key economic drivers such as agriculture, forestry, mining, etc. to improve import/export flow throughout the Commonwealth."[78]

[75] Washington State DOT. Washing State Freight Mobility Plan Task 2: Interim Data Report. January 2014. http://www.wsdot.wa.gov/NR/rdonlyres/881F4A29-E45A-46F6-85E2-D5B1B7510EB3/0/WashingtonStateFreightMobilityPlanTask2InterimDataReport.pdf

[76] State of Montana Department of Transportation. TranPlan 21. 2008. https://www.mdt.mt.gov/pubinvolve/docs/tp21_brochure.pdf

[77] Metropolitan Area Planning Council. MetroFuture. Referenced by the Boston Region MPO in: Long-Range Transportation Plan – Paths to a Sustainable Region. http://www.ctps.org/Drupal/data/pdf/plans/LRTP/paths/2035_LRTP_Chapter2.pdf (page 2-8).

[78] Virginia Office of Intermodal Planning and Investment (2014). Virginia Multimodal Freight Plan. http://www.vtrans.org/resources/FR1_VADOT_Multimodal_FrghtPln_20140930_complete.pdf

Tracking Freight Accessibility Issues	• Minnesota's Statewide Transportation Plan: establishes a framework in which performance measures (cost, travel time, delay, travel speed, congestion) are applied specifically to infrastructure that serves important markets or key freight generators.[79] • Metro Portland's 2035 Regional Transportation Plan: applies a variety of system evaluation measures to scenarios modeled as part of the RTP, including "total delay and cost of delay on the regional freight network in mid-day and PM peak."[80] • Virginia DOT Pilot Project: developed a quantitative methodology for measuring freight and passenger accessibility for intermodal and activity centers, as well as on key corridors. The measures are intended to enable comparison of places and corridors, across modes—as a way of providing a standard basis for discussing accessibility and potential improvements.[81]
Enumeration and Evaluation of Specific Freight Access Issues	• Boston MPO's 2011 Long-Range Transportation Plan: focuses on the issue of port access, including connections to limited-access highways and freight rail lines, as well as availability of overweight-truck routes to/from ports; describes bottlenecks and restrictions that limit truck and rail mobility—but does not explicitly define the effect these limitations have on freight access; highlights the issue of land use and crowding out of industrial and freight-intensive uses by residential and commercial uses as cause for concern—because this loss of land "increases shipping costs and can harm economic competitiveness." [82] • Chicago's Go To 2040 Plan: some of the major capital projects outlined in the plan are directed at freight access (for example, the Illiana Expressway is aimed at providing access to freight and logistics centers in Will County), but the quantitative evaluation measures used in project justification do not include freight access measures.[83]

[79] Minnesota Department of Transportation. Minnesota Statewide Transportation Policy Plan: 2009-2028. http://www.dot.state.mn.us/planning/stateplan/Final%20Plan%20Documents/Policy%20Plan/Entire/Minnesota%20Statewide%20Transportation%20Policy%20Plan_2009-2028.pdf

[80] FHWA (2010). Outcomes-Based, Performance-Driven Planning at Metro Portland. Planning for Operations. http://ops.fhwa.dot.gov/publications/fhwahop10055/index.htm; and Metro (2014). Regional Transportation Plan. http://www.oregonmetro.gov/regional-transportation-plan

[81] Virginia Office of Intermodal Planning and Investment. Measuring the Accessibility of Centers and Corridors in Virginia. http://www.vtrans.org/reports_and_studies.asp#access

[82] Boston Regional MPO (2011). Long-Range Transportation Plan – Paths to a Sustainable Region. http://www.ctps.org/Drupal/data/pdf/plans/LRTP/paths/2035_LRTP_Chapter3.pdf (page 3-13 and 3-10)

[83] CMAP (2010). Go To 2040. Major Capital Projects. http://www.cmap.illinois.gov/documents/10180/31056/GO+TO+2040_major_capital_projects.pdf/53b768a0-28ac-4a53-b42b-2e1590ce5e1b

Table 15 Examples of freight access criteria included in agency prioritization

Agency	Criteria included in prioritization
North Carolina DOT[84]	• Highways: points allocated based on a measure of existing congestion along truck routes and routes that provide access to transportation terminals. • Rail: points allocated to projects that improve rail service accessibility for industries and to projects involving intermodal or transload facilities.
Missouri DOT[85]	• Major Expansion Projects: points allocated to projects that eliminate identified freight bottlenecks and projects that provide better connections to intermodal freight facilities.
Ohio DOT[86]	• Major New Capacity Projects: Up to 5 points allocated to projects that connect two or more modes of transportation (both passenger & freight); up to 10 points assigned on the basis of intermodal freight congestion measures; and up to 10 points assigned for freight capacity increases (measured in TEUs) at specific freight facilities.
Baltimore MPO[87]	• Policy evaluation criteria: Scoring between 0-5 for a project that "Improves access to major activity centers, including businesses, employment centers, ports, and freight intermodal facilities" or "Improves connectivity and efficient movement of freight"[88] • Definition of regionally significant projects: Baltimore designates certain projects that are considered important to the entire region and therefore are not subject to the general project evaluation process. One qualifying criteria for highway projects is that they connect to a major economic "engines" such as a port, airport, or intermodal or freight transfer facility.

[84] North Carolina DOT (2013). Strategic Transportation Investment Implementation Report. https://connect.ncdot.gov/projects/planning/MPORPODocuments/Report%20to%20the%20JLTOC.pdf (Page 23, 29).
[85] Missouri DOT (2009). Engineering Policy Guide; Section 121.2, "The Planning Process," Table 121.2.5.4 - Prioritization Process. http://epg.modot.org/index.php?title=121.2_the_planning_process
[86] Ohio DOT (2013). TRAC – Transportation Review Advisory Council Policies & Procedures. http://www.dot.state.oh.us/trac/Documents/2013%20Policy%20Updates/TRAC%20Policies%20and%20Procedures%20Revisions_7.8.13.pdf (Page 8).
[87] Baltimore Regional Transportation Board (2011). Plan It 2035. http://www.baltometro.org/information-center/documents/category/91-plan-it-2035?download=2185:planit2035aph&start=30 (Page H-2).
[88] Baltimore Regional Transportation Board (2011). Plan It 2035. (Page H-4).

Table 16 Strengths and Challenges of Available Options for <u>User Group</u> Representation

User Group: Access for whom/from where?		
OPTION	STRENGTHS	CHALLENGES
Area centroid (unweighted)	- Simple to compute using GIS - Generic and therefore broadly applicable	- Depending on the scale of the area assessed, can obscure significant local issues (like the circuity of access for a particular key activity cluster not located near the area centroid)
Activity-weighted area centroid	- Provides a programmable decision-rule for approximating the location of freight-generating land uses	- Requires the selection of an additional activity data set for weighting, at a greater level of spatial detail than the zones used for analysis
Freight generator location	- Focuses analysis on key business locations - Is responsive to inquiries and concerns from industry stakeholders	- Selection will either require development of an additional selection methodology, or reliance on local knowledge (thus raising comparability issues across areas and analyses undertaken at different times)

Table 17 Strengths and Challenges of Available Options for <u>Attraction/Destination</u> Representation

Attractions/Destinations: Access to where/what?		
OPTION	STRENGTHS	CHALLENGES
Network Access	- Relatively easy to compute (shortest-path network impedance) - Existing spatial data sets include the location of major highway interchanges, intermodal rail facilities, ports, and airports - Easy to understand - Captures the gateway function of interchanges and intermodal facilities without requiring network representation that extends beyond the region analyzed	- Incomplete representation of accessibility: only captures first/last-mile access and, in some cases, service availability for non-truck modes.
Activity Access	- Translates more directly to theories of "market access" - Provides a more complete representation of freight accessibility - Can be targeted to specialized buyer and supplier markets for a particular industry	- Requires additional activity data (and selection of the appropriate indicator) - Is more computationally demanding (all-to-all calculations of impedances and activity data required for every zone in a study area) - Calculations are in many cases only feasible for truck accessibility and not across all modes (see discussion of Data and Analytical Requirements)

Table 18 Strengths and Challenges of Available Options for Impedance Representation

Impedance: Access at what cost and long which network?		
Impedance Quantification (on a network)		
Option	Strengths	Challenges
Distance	- Can be calculated using built-in GIS functionality without additional information	- Does not capture performance characteristics of the transportation system
Travel time	- Can be sourced from pre-existing travel-demand models or other geospatial data sets, or created on the basis of link classification rules (e.g. higher speeds for arterials than local collectors) - Easy to understand - Captures the dominant dimension of transport costs	- Does not account for other factors that affect total transport costs such as unreliability, loss and damage to goods, tolls and fees, commodity-specific freight carrying cost, etc.
Generalized cost	- More comprehensive - Can facilitate a more targeted understanding based on commodity flows	- No uniform definition of factors to be included - Requires conversion of all factors into monetary units - Requires information on commodity movements - Units do not have intuitive meaning
Network definition (definition of freight-accessible network for impedance quantification)		
Option	Strengths	Challenges
Congested and uncongested (or peak and off-peak)	- Captures congestion effects that are critical to freight access, particularly in urban areas	- Is based on traffic flows and therefore requires detailed data collection on speeds by time of day for all links or travel demand modeling
Truck routes	- Constrains analysis to the sub-network that is actually accessible to trucks, thus capturing more closely the types of localized and geometric issues that are frequently cited by the freight community	- Adds analytical steps: selecting a sub-set of the network and re-running shortest-path algorithms on the reduced network - Requires a definition of minimum functional requirements that may not be appropriate for all truck sizes or freight types - Still may fail to capture other localized issues such as improper signalization

Inter-modal/Multi-modal networks	- Most closely captures the available options for freight movement - Can build upon existing methodologies developed in the academic literature on both freight and public transportation	- Challenging to construct - Accessibility via air, rail, and marine modes is a function of service provision, and thus may vary by time of day (or week) or commodity, and are subject to individualized agreements which may be proprietary
***Functional form of cost*[89]**		
Option	Strengths	Challenges
Contour measure	- Easy to understand and compute - Can account for strict temporal constraints (i.e. one-day-delivery)	- Treats all opportunities equally within the given threshold - The selection of boundaries is always to some degree arbitrary
Potential/gravity measures	- Addresses boundary issues of contour measures - Generates an accessibility measure based on all zones in a region - Functional form (spatial decay) can be tailored for particular industries	- The units of this class of measure do not have intuitive meaning - Parameters that govern the functional form are usually estimated within models and the implications of transference between regions are not fully understood (e.g. the β governing the exponential decay in: $A_i = \sum_{j=1}^{n} W_i e^{-\beta c_{ij}}$)

[89] For more information, see: *Development of an urban Accessibility Index: Formulations, Aggregation, and Application* (2002). Available at: http://www.utexas.edu/research/ctr/pdf_reports/4938_4.pdf; *Urban Accessibility Index: Literature Review* (2000). Available at: http://www.utexas.edu/research/ctr/pdf_reports/4938_1.pdf; Baradaran, et al. Performance of Accessibility Measures in Europe. RITA. Available at: https://2bts.rita.dot.gov/publications/journal_of_transportation_and_statistics/volume_04_number_23/paper_03/ Accessed 14 May 2014.