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Increasing Regional Truck Freight Planning in Virginia

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16. Abstract:

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A survey of Virginia planning district commissions showed that some are interested in specific practices, notably a provision for truck parking during emergencies (of interest to one-half of the respondents), truck parking needs as part of zoning ordinances (one-third of respondents), and a provision for locally funded truck parking areas (one-fourth of respondents). Practices undertaken by a minority of respondents but of high interest to others include identifying critical gaps in the truck freight network based on a lack of resilience, working with a regional freight advisory committee to identify improvements, and identifying load-restricted bridges affecting deliveries for businesses. Resiliency was not explicitly defined in the survey, but Golias et al. (2018) characterized it as "robustness, reliability" such that should one link fail, a resilient network would provide other links for travel.

Piloting one such practice—incorporating truck parking needs into zoning—with one planning district commission showed that tailoring the seven practices this study identified to tightly defined regional interests can encourage truck freight planning. In this particular pilot, the region was interested in ways future land use might stimulate offsite parking demand near delivery points, especially because, in this particular case, parking demand driven by land use was calculated as part of the pilot to increase by 4% during the next 2 decades. The pilot culminated with recommended supporting language included in the county's comprehensive plan as the county planner suggested. A key lesson adaptable to other locations in Virginia is that the practices mentioned in the survey are starting points for engagement in short-term (less than 1 year) truck freight planning efforts with regions.

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FINAL REPORT

INCREASING REGIONAL TRUCK FREIGHT PLANNING IN VIRGINIA

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In Cooperation with the U.S. Department of Transportation
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ABSTRACT

Although the forecast rate of growth for truck vehicle miles traveled is roughly double the forecast rate of growth for passenger vehicle miles traveled, specific planning techniques to address truck freight planning needs are not widely known. Accordingly, to elevate the importance of truck freight within the regional planning process, this study identified seven categories of practices regional planners can initiate, which are coordinating local planning and truck freight planning, using freight advisory committees, monetizing reliability in project prioritization, quantifying truck parking deficiencies, studying truck routing, incorporating truck freight into scenario planning or regional modeling, and obtaining freight data from public sources.

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EXECUTIVE SUMMARY

Although truck freight transportation is expected to grow at roughly twice the annual rate of passenger vehicle miles traveled during the next 30 years (FHWA, 2020), specific techniques that can be taken to better address truck freight needs within the regional planning process are not widely known (TPRAC, 2021). Three challenges exacerbate this problem. First, specific freight planning techniques are not necessarily clear because they may differ from passenger-oriented planning (Guo and Wittwer, 2009), which received more attention than passenger-oriented projects in a national review of metropolitan planning organizations (Schank et al., 2008). Second, Virginia does not have updated information on the freight interests of its regional planning partners: planning district commissions (PDCs), that is, what are the truck freight planning practices these entities are undertaking? Third, if a practice is not undertaken, are there PDCs interested in such a practice? In such cases, the effort required to implement freight planning practices and the benefits they provide may not be known, a situation that could be especially problematic for PDCs with small staff.

Therefore, this study sought to identify truck freight planning practices that if started at the regional level can achieve these objectives:

- Identify practices employed by and of interest to Virginia PDCs.
- Illustrate how to apply practices in Virginia with key stakeholders.

The study's emphasis was on practices that could be implemented at a small scale, such as with a small staff or with a modest use of consulting services and completed in within a year.

Identify Feasible Truck Freight Planning Practices

To support the awareness elevation of truck freight within the regional planning process, this study identified seven categories of practices regional planners can initiate: coordinating local planning and truck freight planning; using freight advisory committees; monetizing reliability in project prioritization; quantifying truck parking deficiencies; studying truck routing; incorporating truck freight into scenario planning or regional modeling; and obtaining freight data from public sources (Table ES-1). A review of the literature was conducted to identify these categories, and then an example of implementation was identified, based on interviews with staff from the state department of transportation, city, or metropolitan planning organization that had used the practice or through implementing the method on a small scale in Virginia.

Although these practices benefit from regional support, they cannot be implemented fully at the regional level. Consider, for instance, the coordination of local planning and truck freight planning. Specific practices, such as reservation of street space for truck parking or modification of local zoning ordinances to allow truck parking requires municipal or county authority. Some practices in Table ES-1 require state authority such as state financial support for private sector participation in regional freight advisory committees, using the value of travel time reliability to evaluate freight project benefits or to quantify truck parking deficiencies by allowing trucks to use park-and-ride lots at night.

Table ES-1. Categories of Truck Freight Planning Practices

Category	Practice	Example
Coordinate local planning and truck freight planning.	Model ordinances to support onsite parking.	Incorporate truck parking needs as part of zoning ordinances when industrial areas are being developed.
	Use local funds for truck parking area.	Investigate the use of county, stadium, or mall lots to provide truck parking or designate truck-only parking on certain streets.
	Develop freight consolidation centers to reduce urban last vehicle miles traveled (VMT).	Work with private businesses (or diverse functional units within the same business) to have a single location for deliveries within a particular urban area.
Use a freight advisory committee (FAC) to identify changes.	Develop a regional FAC to suggest long-term transport investments and zoning policies.	Through zoning, preserve land at the port for freight or industrial uses.
	State-funded support for regional FACs to direct funds for short-term operational changes.	With a small funding pot, identify 1-year intersection improvements for trucks.
Monetize reliability in truck project prioritization.	Quantify freight project benefits based on average value of time to quantify freight project benefits.	Evaluate freight projects based on the number of truck hours reduced (e.g., use $67 per truck hour in a sample calculation).
	Quantify freight project benefits based on the value of reliability.	Evaluate freight projects based on reduction in reliability costs (e.g., use $369 per truck hour in a sample calculation).
Quantify truck parking deficiencies.	Estimate existing options for emergency truck parking.	Identify options for truck parking during emergencies within a state or region. For example, Virginia has 297 park-and-ride lots that are possible options.
	Examine local ordinances that concern truck parking.	Identify regulations in Virginia counties, cities, and towns that stipulate when and where trucks may park.
Study truck routing.	Compare truck travel paths with the designated truck freight network.	Based on StreetLight Insight®, identify instances when large numbers of truck trips are off established truck routes.
	Experiment lane management strategies to accommodate trucks.	On a pilot basis, determine if certain transit-only lanes can accommodate trucks without adversely affecting delay because of different truck and transit peak times.
Incorporate truck freight into scenario planning or regional models.	Incorporate truck freight trips into the regional travel demand model for smaller metropolitan planning organizations.	Use information from the *Quick Response Freight Methods* to estimate truck trips needed for the regional model.
	Plan scenarios with respect to investments and land development.	Use the regional model to examine how a mix of investments and various warehouse locations affect VMT and delivery delay.
Obtain freight data from public sources.	Use innovative data sources or technologies to improve freight data.	For various commodities, such as timber, identify origins and destinations from public sources to infer locations of high demand.

All practices carry some type of financial or political cost. One interviewee noted that increased zoning requirements might reduce a locality's ability to compete for industrial businesses. However, regional staff can start the analysis required to support these practices by

identifying the benefits, costs, and feasibility of initiatives through the regional planning process. For example, consider the practice of comparing truck travel paths with the designated truck freight network. For an implementation example of interest to Virginia stakeholders, the research team found that roughly one-half of heavy trucks traversing between the two areas served by Route 15 used that truck-restricted route. It is conceivable, but it has to be proven that the remainder of the truck traffic would benefit from using Route 15 if it were legal (and safe) to do so.

Survey of PDC Interest in Freight Planning Practices

During June through August 2022, 22 representatives from Virginia's planning districts and 10 respondents from the Virginia Department of Transportation (VDOT) districts completed a survey regarding 50 truck freight planning practices, indicating practices (1) currently performed and (2) not currently performed, and (3) that generate the greatest interest among PDCs.

The survey results show that PDCs are heterogeneous. Of the 50 practices, no practice interested all PDCs. On average, any given practice was either already undertaken or of high interest to roughly one-third (37%) of respondents. Some practices appear to have little chance of garnering regional or local support because they have not been implemented nor is the practice generating interest. Two examples are truck toll pricing studies and freight consolidation centers.

The survey results also show that PDCs have substantially different interests. For instance, seven PDCs were highly interested in the practice of incorporating truck parking into zoning ordinances, but another seven respondents expressed little interest. The division between urban and rural areas does not explain this difference in interest levels. Of the seven PDCs that indicated little interest, four were from fairly urban locations (Northern Virginia's two respondents: George Washington, which includes Fredericksburg Area Metropolitan Planning Organization and the Tri-Cities) and three from rural locations (Lenowisco, Cumberland Plateau, and Central Shenandoah).

The results suggest two opportunities for improving the planning process. First, some PDCs are highly interested but are not currently undertaking certain practices that could be piloted in Virginia on a case-study basis. Key practices are providing truck parking during emergencies (of interest to one-half of the respondents), incorporating truck parking needs as part of zoning ordinances (one-third of respondents), and using locally funded truck parking areas (one-fourth of respondents). This finding led to the researchers' decision to pilot one practice in one PDC as part of this research.

Second, a minority of PDCs undertake other practices, which are of high interest to several other PDCs. This fact suggests that certain PDCs may be amenable to sharing information with other PDCs or between with VDOT. Candidate practices for sharing include identifying critical gaps in the truck freight network based on lack of resiliency, working with a regional freight advisory committee to identify improvements, and identifying load-restricted bridges affecting deliveries for businesses. In this regard, a followup step could be information sharing at a statewide event.

Pilot One Practice in One Region

During an 8-month period, one freight planning practice suggested in the literature and of interest to roughly one-third of Virginia planning districts—how to incorporate truck parking into zoning considerations—was examined at a single location: Warren County within the Northern Shenandoah Valley Regional Commission (NSVRC). Because trucks may need parking at an offsite location near where they deliver their goods or rest after a long drive, the original question was how changes in employment in freight-intensive industries, such as manufacturing, wholesale trade, and warehousing, might influence this need for offsite parking? Then the scope of the pilot was modified to address three questions of interest to participants:

1. Were truck patterns different before the COVID-19 pandemic from today's truck patterns?
2. What is the forecasted increase in demand for truck parking based on changes in Warren County's employment?
3. To what extent does the fact that Warren County has an interstate corridor affect that forecast?

The results show that the pandemic does not appear to have materially altered truck patterns originating from Warren County. For example, of all freight by truck originating in Warren County, 6.2% terminated in Shenandoah County in 2019 compared with 5.6% in 2021.

The results also show that although parking demand at truck rest areas may grow 26% during 2 decades (based on calculations performed as part of the pilot and shown in Figure 16 in the body of the report), another potential consideration is staging, i.e., having adequate offsite locations to situate trucks before or after unloading. For the area within Warren County (e.g., 0.1 to 11.0 miles of the county's centroid), estimated demand attributed to land development is considerably greater than estimated demand attributed to traffic stopping at private and public truck facilities. For the former, using the Federal Highway Administration's truck parking estimation tool, the research team estimated a demand of 483 spaces for 2045 (staging, rest, and long-term parking, which may or may not occur at a truck facility) compared with 107 spaces based on through traffic stopping at designated truck facilities). A review of Google maps for the entire NSVRC (not just Warren County) showed 31 instances of a truck being parked adjacent to the roadway. In some cases, the truck was near a rest area, and in other cases, it was near a potential delivery point.

A potential action item that the locality may undertake would be including language in its comprehensive plan that supports consideration of truck parking when industrial sites are developed. Wendling (2023) provided an example of language the locality could include in its plan:

> Tractor trailer truck parking spaces shall be incorporated into site plans for warehousing and distribution centers in the corridor to allow for periodic rest stops as a service for long haul freight truck drivers. These parking areas should be clearly identified for short-term use from a half-hour to 12-hour time limit. Such parking may be located within the industrial park or may be satellite location set aside for this purpose. Rezonings may also provide an opportunity to request proffers for the areas to be designated as part of the General Development Plan.

The previous language is tailored to the specific Warren County, the pilot county. The spirit of considering truck parking within zoning regulations may be accomplished through a spectrum of options. This pilot showed one way the community and stakeholders can engage to consider those options.

Conclusions

1. *Seven categories of truck freight planning practices that could be initiated at the regional level have been identified*. Working alone, the regional planner cannot fully implement the practices but can support them.
2. *The survey of PDCs suggests that a sizeable percentage of PDCs have high interest in but are not performing certain freight-related planning practices*. These practices include providing truck parking during emergencies, examining ways short truck trips may be an opportunity to introduce electric trucks, incorporating truck parking needs as part of zoning ordinances when sites are developed, and using local funds for truck parking areas. These practices may be a good fit for future pilot efforts.
3. The survey of PDCs suggests that *a sizeable percentage of PDCs are highly interested in certain freight-related planning practices that other PDCs are already implementing,* for example, identifying critical gaps in the truck freight network based on lack of resiliency and working with a regional freight advisory committee to identify improvements. These practices may be amenable to information sharing among PDCs.
4. *The interests of the PDCs are heterogeneous.* No practice was universally popular, but each practice either generated interest or was implemented by at least one PDC. This observation of heterogeneity is not surprising when compared with the literature because several of the practices appear feasible nationally but only under very specific circumstances. For instance, the local provision of truck parking (Carson City) appears to have resulted in response to a request from local businesses.
5. *The process of conducting the pilot suggests that truck freight planning can be encouraged by tailoring techniques to tightly defined regional interests.* The process of modifying the pilot scope to the region's key questions (e.g., how demand for offsite parking might grow, what is the impact of through traffic on this demand, and the ways freight patterns have shifted since the onset of the pandemic) led to a series of analyses that answered technical questions but also supported discussion among participants. The culmination of the pilot demonstrated an opportunity for localities to help address parking needs: the inclusion of supporting language in the county's comprehensive plan as the county planner suggested. The planner also noted that maps provided during the pilot were a key ingredient for this language. A key lesson is that the practices mentioned in the survey are starting points for engagement of regions in truck freight planning efforts. Keeping the pilot short—aiming for 4 to 6 months and taking about 8 months total—helped ensure a product could be delivered in a timely manner.

Recommendation

VDOT Transportation Mobility Planning Division should take discrete, actionable steps to encourage PDCs, in consultation with VDOT district planners, to conduct truck freight planning. The Implementation and Benefits section discusses three such action items.

INCREASING REGIONAL TRUCK FREIGHT PLANNING IN VIRGINIA

INTRODUCTION

Truck freight transportation accounts for approximately 7% of total vehicle miles traveled (VMT) on Virginia public roads (VDOT, 2020). Furthermore, truck freight transport is expected to grow nationally at roughly twice the current annual rate of passenger VMT during the next 30 years (Federal Highway Administration [FHWA], 2020). FHWA forecast annual VMT growth rates of 1.3% for heavy trucks and 2.2% for single unit trucks compared with 0.8% for light duty vehicles (FHWA, 2020). Freight's importance to regional economies is evident in Virginia: The Staunton-Augusta-Waynesboro Metropolitan Planning Organization explicitly identified a dozen major large-scale warehouses in its 2045 long-range plan, noting that roughly $1.2 billion in goods were shipped from the metropolitan planning organization (MPO) during a 5-year period. The plan further noted that a goal of planning is to "strengthen the ability of rural communities to access national and international trade markets" (SAWMPO, 2020). Still, despite freight's importance, specific techniques that can be implemented to better address truck freight needs are not widely known, leading the Transportation Planning Research Advisory Committee (2021) to cite as a research need the identification of best practices for truck freight planning, with the implication that such practices are targeted at regional transportation planners.

The need to research and apply techniques to improve truck freight planning is echoed nationally. Entities charged with regional planning recognize the importance of freight within the transportation planning process. Cambridge Systematics et al. (2007) noted that most (90%) of small- and medium-sized MPOs address freight in their long-range plans. However, the same authors point out that in some locations, passenger planning receives greater attention. A member of one local agency explained that "freight does not vote and passengers do." Three challenges to increasing freight's inclusion in the planning process remain.

First, the meaning of "freight planning" may not be clear. Guo and Wittwer (2009) suggested that freight planning receives less emphasis not because it is undervalued but because specific steps agencies should take are not clear. Freight investments "are often outside of the norm of projects considered in a plan or program" and have different stakeholders than passenger-oriented projects. Schank et al. (2008) agreed that freight planning receives less emphasis than passenger planning, a finding supported by a survey showing that typically less than 5% of MPO staff time was devoted to freight projects.

A second challenge is that Virginia does not have a centralized data source comprised of the interests of its planning partners. As one example, the *Code of Virginia* (§ 46.2-1224) allows localities to enact ordinances that restrict parking along various roads in the locality if the vehicle, whether an automobile or a truck, is being used for "for commercial purposes" (Commonwealth of Virginia, 2021). For vehicles used to carry long-haul freight, notably tractor trailers, a comprehensive list of such restrictions could help the Commonwealth better plan for meeting drivers' needs for truck rest area locations. However, at the time this study began, VDOT did not have a comprehensive list of such ordinances. The lack of such data can hinder truck freight planning efforts. Because land use decisions, such as the allowance of truck parking on certain streets, and policies that support the development of off-street parking locations are

the purview of planning district commissions (PDCs) and localities, VDOT needs to better understand the extent to which truck freight planning initiatives are of interest to PDCs and local planning agencies.

Third, freight competes with other planning priorities. A review of street loading requirements in 23 U.S. cities showed insufficient loading areas, but a Philadelphia official noted that if loading zones would affect pedestrians (e.g., an additional curb cut), the city would "have to reevaluate the proposal" (McDonald and Yuan, 2021). Two groups of literature encapsulate this competition: truck roadway damage and truck transport benefits. Nassif et al. (2016) found that each ton-mile of overweight freight in New Jersey caused 13 cents worth of pavement damage. Mallett et al. (2004) found the value of reducing carrier delays to be $144 to $192 per hour. These sources are not contradictory, rather they show different perspectives regarding truck freight planning: One sought to recover damage trucks cause, and the other targeted ways to improve their mobility.

Given an interest in improving truck freight planning, the problem facing Virginia consists of three factors:

- Best freight planning practices are not necessarily understood.
- The interests of Virginia's planning partners in such practices are not documented.
- The degree of effort required to implement one or more of these practices is uncertain.

PURPOSE AND SCOPE

The following list shows the purpose of this study:

- To identify truck freight planning practices that can be started at the regional level.
- To identify practices employed by and of interest to Virginia PDCs.
- To illustrate to key stakeholders in Virginia how to apply practices.

The scope of the first objective was limited to identifying practices but not prioritizing them, given that regional interests may vary.

The second objective targeted only one of several entities that could address freight planning: PDCs. The Virginia Association of PDCs (2023) quotes the *Code of Virginia* (§ 15.2-4207), which states that PDCs serve to "facilitate local government cooperation and *state-local cooperation* in addressing, on a regional basis, problems of greater than local significance" (emphasis added). Given this emphasis in the Code, the PDCs were viewed as a source for capturing the views of their member localities.

The third objective was limited to learning lessons from applying one practice in one region by conducting a case study to illustrate how to repeat the application of the practice in other locations.

METHODOLOGY

The research team completed these four tasks:

1. Developed examples of best practices.
2. Conducted a survey of PDCs.
3. Applied one practice to one region as a case study.
4. Incorporated survey information and case study feedback from the Technical Review Panel (TRP).

Develop Examples of Best Practices

Initially, the research team conducted an initial search of the Transportation Research in Information Database, using truck freight planning terms such as planning practice, freight, freight planning, truck, and freight demand on June 24, 2021. Later, on October 21nd and December 21st of the same year, this search broadened to include more terms. Initial searches and, in some cases, contacts by phone or email to agencies led to other publications or insights. For instance, FHWA (2017) highlighted the use of freight advisory committees (FACs) in 2012. As this information was a decade old, the research team contacted two planners from a MPO regarding their FAC.

The research team focused on two key elements with regard to the aforementioned articles: (1) those that showed why it is important to complete certain planning activities and (2) those that showed how to perform these activities. An example of the former is Beagan et al. (2019), which noted that because site planning and regional transportation planning require knowledge of how many truck trips are generated and where these trips are distributed, planners need ways to obtain freight data. An example of the latter is the Guerrero et al. (2019) study that suggested monetizing the value of truck freight reliability, which was the difference between the mean travel time and the 95th percentile travel time.

Once practice information was gathered, the practices were categorized based on similarities. For example, the practice of examining truck routing decisions and the practice of allowing trucks into transit lanes were placed in the category of studying truck routing. Then, for each category, an implementation example was identified with sufficient detail to be replicated. This detail was obtained by developing an example of the practice and either applying the practice to a small dataset specific to Virginia or by conducting an interview with practitioners to understand how the practice had been implemented elsewhere.

Conduct a Survey of PDCs

Survey Development

The main purpose of the survey was twofold—to identify the best practices PDCs use that are not captured in the literature review and to identify practices that, although not undertaken by MPOs at present, might generate their support for the future. Because PDC staff members who support MPOs are familiar with the 10 federal planning factors (as one study

champion noted), the practices from the literature were organized around these factors, even though it was a different categorization than that in Task 1.

Although trucks are not explicitly mentioned in the factors, FHWA and the Federal Transit Administration (FTA) (2019) provided additional guidance that illustrates those organizations' breadth. For instance, the first planning factor, "Support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency," could be supported by a practice that FHWA and FTA advanced, which is "defining elements of a metropolitan area's transportation system that are critical for the efficient movement of freight." To shorten the survey, two planning factors were combined: Planning factor 2, "Increase the *safety* of the transportation system for motorized and nonmotorized users," and planning factor 3, "Increase the *security* of the transportation system for motorized and nonmotorized users." Then, the research team completed the following five key steps to compose the survey instrument.

- *Reviewed Virginia-specific MPO plans to identify other practices.* For example, the Roanoke Valley Transportation Planning Organization (2017) sought to relate indicators of freight demand, such as shipment volume and number of truck trips, to the number of employees by economic sector (e.g., manufacturing). Accordingly, a practice of "Infer freight flows from other data sources such as business locations" was added to the survey.
- *Added practices suggested to the research team.* For example, the Virginia statewide FAC noted the practice of identifying load-restricted bridges that affect key businesses. Each VTRC study, including this one, benefits from a group that helps guide the study's scope and direction—the TRP. In March 2022, the TRP noted that "critical gaps" in the network could refer to either limited capacity or truck restrictions, such that both concepts merited consideration. For the practice "Does your agency identify any low bridges that affect deliveries," the TRP suggested the additional phrase "to/from businesses" to distinguish this from a practice of identifying low bridges that affect deliveries "to/from the military."
- *Consulted literature for information on survey design.* One practice concerned the use of various criteria (such as geometric deficiencies or truck restrictions) to identify critical gaps in the freight network. However, literature on survey design, such as Pew Research Center (2022), advises against asking about multiple topics in the same survey question. Accordingly, the original practice was separated into five separate practices that identify gaps in the truck freight network based on (1) truck restrictions, (2) missing links, (3) geometric deficiencies, (4) lack of resiliency (e.g., flooding), and (5) limited capacity. Kriger et al. (2011) explained how truck freight surveys (for the purposes of collecting origin-destination data, not surveying transportation planners) supported specific practices such as "analysis of the movement of hazardous materials" and "toll feasibility analysis" that were added to the survey.
- *Performed an editorial review of the paper-based survey questions.* An editor familiar with survey design recommended changes such as breaking two-part questions into two separate questions, revising the federal planning factor titles, and indicating the number of planning factors in the introductory letter. Then a separate individual with extensive

survey experience recommended further changes, such as replacing the nominal phrases such as "no interest," "somewhat interested," and "very interested," with a scale (e.g., 1 indicating no interest and 3 indicating very interested). Other suggestions included using a five-point, rather than a three-point scale, and making each practice a question, rather than a statement.

- *Coded the survey into two platforms and requested feedback on the survey.* Conversion of the survey to Google Forms revealed a problem: whereas each practice could be answered with a single marking on paper (Figure 1), a computer version required four markings (Figure 2), which was problematic for a large number of practices.

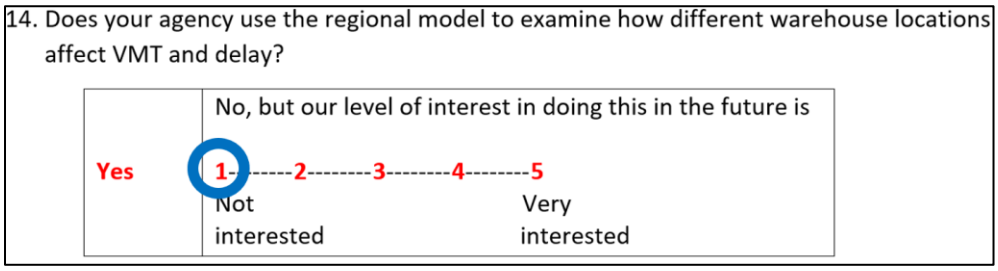

Figure 1. Completing the Survey on Paper with a Single Marking (Shown in Blue)

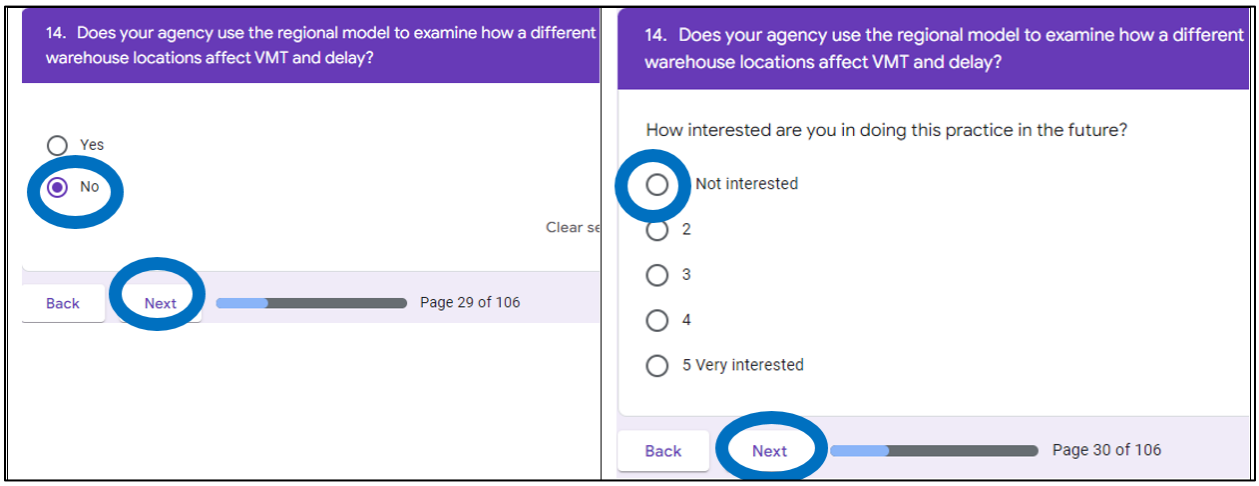

Figure 2. Completing the Survey with Four Markings (Shown in Blue)

In response, the researchers revised the survey to have only one response per practice. Then, the researchers tested the survey across two platforms: Google Forms and Qualtrics. Ultimately, the research team chose Qualtrics, based on TRP feedback that Qualtrics was easier to follow, and it offers a friendly mobile version that could be used in case respondents chose to respond to the survey by phone, rather than by computer.

Figure 3 shows the final desktop version of the survey, and Figure 4 shows the survey version for response by mobile device.

	YES	NO, and my level of interest in doing this in the future is 1 (Not interested)	NO, and my level of interest in doing this in the future is 2	NO, and my level of interest in doing this in the future is 3	NO, and my level of interest in doing this in the future is 4	NO, and my level of interest in doing this in the future is 5 (Very interested)	NO, and my level of interest in doing this in the future is Don't know
33. Does your agency identify any low bridges that affect deliveries to/from businesses?	○	○	○	○	○	○	○

Figure 3. Example of a Survey Question for Practice 33

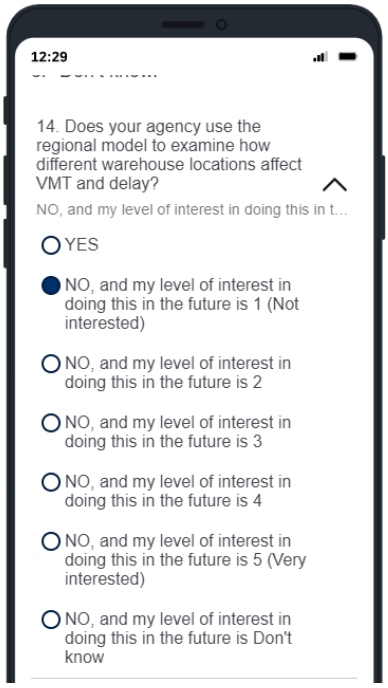

Figure 4. Excerpt of the Survey in Qualtrics on a Mobile Device

Survey Deployment

A presentation on regional truck freight planning practices was made at the MPO Quarterly Coordination and Annual Planning and Programming Meeting held on June 7, 2022 (Miller, 2022). The bulk of the presentation described practices from the literature that planners could undertake (e.g., regional FACs, incorporation of the value of reliability in project prioritization, or truck routing). The presentation concluded with telling the audience—largely comprised of representatives from PDCs and VDOT district planners of an upcoming survey designed to gauge their interest in various planning practices. The president of the Virginia

Association of MPOs had suggested that this meeting was a good opportunity to make PDCs aware of the survey.

The survey was distributed on June 10, 2022, to PDCs and VDOT district planners and, after 2 weeks, individuals who did not respond were contacted by email or telephone and asked to provide a response. Additional followup contacts were made as necessary. In addition, TRP members encouraged responses through various channels such as the monthly district planning managers' meeting.

Apply One Practice to One Region

A case study was conducted in which one promising practice was applied to one region of Virginia. Candidate promising practices were identified based on the results of the survey; practices that generated more interest than other practices were candidates for the study. One such practice was to incorporate truck parking needs as part of zoning ordinances for which approximately one-third (7 of 22) of PDCs had a high interest in this practice. Furthermore, a TRP member had suggested that because localities control land use, the alignment of zoning and truck parking needs with district planning might be a highly productive planning practice. The Northern Shenandoah Valley Regional Commission (NSVRC) was chosen as a location, which is largely rural like five of the other six respondent locations that indicated a high interest; those respondents were Mount Rogers, New River Valley, Central Virginia, Southside, and Commonwealth Regional.

The case study was conducted by first contacting the PDC to determine if it would be interested in participating, at which point the research team presented the idea at a quarterly technical advisory committee meeting organized by the PDC. The practice was expanded into a series of steps. At that initial meeting, representatives expressed both interest in the topic and concerns about the scope. Accordingly, two followup meetings were held to refine the scope of the case study so that it could be completed within a few months. The first meeting focused on the case study goals. The second meeting looked closely at methods and data sources.

Then, the case study began. Because the PDC was interested in a related topic—ways truck patterns might have changed between 2019 and 2021—the study team pursued that topic first. Then, because the PDC and a TRP member were also interested in how often truck parking occurred at non-truck stop locations, the research team performed an analysis of current truck-parking behavior.

Focusing on one county—Warren—in which the PDC had a supportive partner, an analysis was performed to examine how many truck parking locations were needed to accommodate the industrial and warehousing businesses in the county. Both existing and future truck parking locations did not have to be at the business sites or warehouses. They could be away from the business sites to serve truck drivers leaving a site, who would eventually need to stop and rest. A comparison of the results from the case study with other sources of information on this topic and proposed language that could be incorporated into interested localities' comprehensive plans were included in the case study, as participants suggested.

Incorporate Feedback from the Technical Review Panel

Periodically, the research team shared results with either TRP or subsets of TRP in different venues. The research team used comments received to adjust the case study's next steps. For example, the research team had a chance to present an excerpt of the literature review at the statewide FAC meeting held on December 1, 2021, in which one private-sector attendee remarked that understanding whether load-restricted bridges affect deliveries to businesses would be helpful. As a result of that interaction, the team added the suggested practice to the list of practices gleaned from the literature review.

RESULTS AND DISCUSSION

Develop Examples of Best Practices

Seven categories of practices were developed:

1. Coordinating land planning and truck freight planning.
2. Using FACs.
3. Monetizing reliability in project prioritization.
4. Quantifying truck parking deficiencies.
5. Studying truck routing.
6. Incorporating truck freight into scenario planning or regional models.
7. Obtaining freight data from public sources.

Coordinating Land Planning and Truck Freight Planning

Overview

One element of truck freight planning entails coordination between the transportation agency and the locality that holds zoning and site approval powers. A regional organization, like a MPO is a suitable entity to perform the three types of coordination that the research team identified.

- *Model ordinances to support onsite parking.* The North Central Texas Council of Governments (2018) identified a contradiction among "38 regional ordinances limiting truck parking," given that cities are generators of truck freight. The Township of Upper Macungie (2021), Pennsylvania, requires onsite parking and stipulates that in addition to providing sufficient parking for all vehicles that will be stored on the lot, there must also be one truck parking space for every two loading docks. Such ordinances support staging so that trucks have a place to park if they arrive prior to their scheduled loading or delivery time (Julien, 2021).
- *Direct local provision of truck parking areas.* Kohler (2021) suggested that cities have areas (e.g., stadiums or undeveloped sites) that can be used for truck parking. Examples of cities with municipal truck parking are Elmira (New York) and Weed (California). Fisher (2016) explained that creation of the lots shifted trucks from streets and reduced citizen complaints. FHWA (2018) reported on these cities and two others in California—

Carson and Moreno Valley—which designate truck parking on certain city streets. In both cities, trucks can park at specified locations for up to 72 hours. An interviewee from the City of Carson noted that these 72-hour parking spots might have come about because of special requests from the owners of warehouses and industrial parks who needed the spots for their drivers or from the truck drivers themselves (Kim, 2022).

- *Consider freight consolidation centers.* A freight consolidation center is a staging location near an urban area that serves as the last mile for delivering or receiving a freight shipment (Rhodes et al., 2012). Nashville's Vanderbilt Medical Center uses a consolidation center where there were previously many uncoordinated freight deliveries because of the medical center's immediate and diverse needs. A third-party logistics provider that transports supplies for patients is responsible for managing the supply of materials to the individual wards. One positive aspect of this arrangement (a consolidation center where a single entity coordinates truck deliveries) is the reduced space required for inventory. For 12 years, "volumes climbed by a factor of 10 or more, while truck activity remained constant" (Rhodes et al., 2012). Dreischerf and Buijs (2022) pointed out that the economic viability of such centers depends on the extent to which the "last mile" cost savings offset operations costs. However, such offsets are unlikely to materialize unless suppliers use the center to change their distribution methods. The U.S. Department of Energy (2020) further points out that, in general, the vehicle type used for the "last mile" portion of the delivery affects the societal impacts of innovative delivery methods.

Implementation Example

Cattan (2022) suggested that the Elmira lot in New York succeeded for several reasons. The lot has existed for many years as a pay lot. In the past, the lot did not have a pay station; rather, fees were posted and drivers mailed payments to avoid being ticketed. In roughly 2018, the city placed meters on the street and a pay station in the lot, which led to the current $5 daily fee. Generally, the lot is used late at night, and truck drivers have been appreciative that there was some thought for their safety. The lot is located on a street near other commercial establishments and not in a residential area, which offers two benefits: (1) some businesses may benefit from the additional customers and (2) the lot does not affect residential neighborhoods.

The Elmira lot conditions are instructive because none of the foregoing initiatives (model ordinances, publicly available lots, or freight centers) have been widely implemented. Rather, an appropriate local context is essential. An Arizona MPO representative explained two key challenges to changing local ordinances to support truck parking in Arizona (W. Randolph, personal communication, January 27, 2022). First, in areas where available land may be scarce, an industrial landowner may wish to use as much of the parcel as possible for business purposes. Second, a local ordinance specifying additional parking for trucks may weaken a locality's ability to attract employers. Although an Oslo, Norway, pilot consolidation center failed primarily because the venture was not profitable, cascading institutional barriers, such as carriers being concerned with sharing data with a third party, compounded the problem (Nordtomme et al., 2015).

Using Freight Advisory Committees

Overview

A FAC is a well-known mechanism for garnering private sector support (Cambridge Systematics et al., 2007; Guo and Wittwer, 2009; McNally and McCoy, 2018). The Duluth-Superior Metropolitan Interstate Council (2021) noted that its Harbor Technical Advisory Committee has addressed concerns such as mitigation of freshwater corrosion; reservation of land near the harbor for access to marine channels (supported by the MPO's land use plan); and reuse of dredged material. Chicka (2017) indicated that the FAC is a "model" for stakeholder involvement and receives MPO staff support. Boris and Murray (2018) noted that such committees also provide critical data elements that cannot be obtained publicly, thus serving as "data interpreters" (quotes in the original) to help identify improvements (or topics) of greatest relevance to the freight industry.

However, FACs are difficult to maintain. One publication singled out the Bend MPO for its use of a FAC for identifying freight projects, noting that the committee composed of "local shippers, receivers, and carriers" served to help guide the MPO's long-range plan (Wilbur Smith Associates and S. R. Kale Consulting, 2010). Since that time, the MPO has considered convening the FAC but declined to do so because the City of Bend thought that the designation of truck routes was not essential for its 2019 plan (Napoli, 2021). As of 2021, the committee had not been active and was not expected to be reconvened given the area's relatively high land costs, and hence, the lack of growth of distribution centers (Deke, 2021).

Implementation Example

One incentive for continued private participation is to provide funds that members can direct to specific needs. In the Tampa Bay area, the Goods Movement Advisory Committee was started roughly 15 years ago by staff of District 7 of the Florida Department of Transportation (Hunter, 2022). To avoid the long planning horizon typically associated with infrastructure projects, the district created a $2 million annual fund reserved for freight-specific operational or design improvements; and the advisory committee helps select these improvements. The horizon for implementation is typically about 1 year, with costs ranging from $75,000 to $500,000; these costs cover shorter term investments such as turning radius improvements, median modifications, and turn length extensions. An example is a $90,000 median modification that enables trucks to make U-turns and left turns better (Hunter, 2022).

Monetizing Reliability in Project Prioritization

Overview

Traditional measures for monetizing travel time reductions are based on reducing mean travel time. A typical value is $67 per hour based on operational expenses, such as driver wages and benefits, insurance premiums, fuel, and truck lease payments (Guerrero et al., 2019; Williams and Murray, 2020). Because inventory in transit is not available, the "holding cost" moderately increases this travel time savings (Fricker and Whitford, 2004). For example, if a

truck carried 27 tons of machinery, which has an average value of $9,186 per ton (BTS and U.S. Census Bureau, 2020), the total shipment value would be $248,030. With an annual holding cost of 35%, 1 hour of delay saved would amount to $9.91. If this inventory were seven new motor vehicles (average vehicle is $40,000), the holding cost would increase to $11.19.

Guerrero et al. (2019) found that the value of reliability (difference between the 95th percentile time and the mean travel time) exceeded that of mean travel time or even the holding cost because "unreliability" increases costs, thereby forcing truckers to build extra time into their operations and shippers to plan for unexpected supply chain disruptions. A survey of more than 1,000 motor carriers and shippers yielded an overall value of reliability of $160 per truck hour, as shown in columns 3 and 4 of Table 1.

Table 1. Estimation of Travel Time Benefits and Reliability Benefits for a Sample Project

		All Commodities		Highest Value Commodity	
Category (1)	**Variable (2)**	**Before (3)**	**After (4)**	**Before (5)**	**After (6)**
Value of time	Volume (trucks/hour)	12	12	12	12
	Mean travel time (hours)	0.42	0.33	0.42	0.33
	Value of travel time (dollars/truck-hour)	$67 [a]	$67 [a]	$184 [b]	$184 [b]
	Travel time cost (dollars/hour)	$335	$268	$920	$736
	Travel time savings due to the project	$67		$184	
Value of reliability	95th percentile travel time (hours)[c]	0.79 [c]	0.51	0.79 [c]	0.51
	95th percentile travel time, mean travel time (hours)	0.37	0.18	0.37	0.18
	Value of reliability (dollars/truck-hour)	$160 [a]	$160 [a]	$271 [b]	$271 [b]
	Cost of unreliability (dollars/hour)	$710	$342	$1,203	$579
	Reliability savings due to the project	$369		$624	
Total benefits of the project during a 1-hour peak period		$436		$808	

[a] Hourly value taken from Tables 4–12 of Guerrero et al. (2019).
[b] Hourly value taken from Tables 4–5 of Guerrero et al. (2019); all other commodities shown had lower values.
[c] Computed as free flow time × (17.626 × EXP (−2.872 / (mean travel time / free flow time)). For instance, 0.25 hours free flow time × 17.626× EXP (−2.872 / (about 0.42 hours / 0.25 hours)) yields 0.79 hours. A more complex process can be used to calibrate this approach to local conditions (Guerrero et al., 2019).

Implementation Example

One may suppose that a project that will reduce the mean travel time for a dozen trucks by 5 minutes during the peak period, from 25 to 20 minutes (about 0.42 to 0.33 hours). In this project, the free flow travel time is 15 minutes (0.25 hours). Although the value of reducing the mean travel time yields 1 hour, the value of the reliability increase is much higher at $369 (16.52 minutes – 5 minutes) ($160 per truck-hour) (12 trucks) / (60 minutes per hour) = $369. The total freight-related value of the project is thus $436, as the last row that summarizes columns 3 and 4 of Table 1 shows. Not only is the hourly value of reliability higher (e.g., $160 versus $67), but the 35% reduction in the 95th percentile travel time dwarfs the 20% reduction in mean travel time. Higher value commodities could generate greater savings, as shown in columns 5 and 6 of Table 1.

The hourly values shown in Table 1 are considerably higher than those published elsewhere. For instance, guidance for economic analyses used by U.S. Department of Transportation (2021) refers readers to White (2016), who suggested that for local surface travel,

the hourly value of time should be $27.20 for truck travel in 2015 dollars. White (2016) acknowledged the importance of reliability but noted that the agency is "not yet prepared to provide guidance for routine valuation of reliability."

Quantifying Truck Parking Deficiencies

Overview

One way to build possible support for innovative parking solutions is to quantify unmet parking needs. Golias et al. (2020) developed web-based tools providing utilization rates for Tennessee lots (e.g., more than three-fourths of the spaces are filled about 18% of the time). Koliou et al. (2022) sought to develop an inventory of locations that, although not expressly designed to accommodate truck parking, could do so during an emergency. Candidate locations included, for example, a lot adjacent to a supermarket that was more than 10 miles away from any other truck parking lot.

One solution for filling the gap between truck parking demand and supply is allowing truck parking at park-and-ride lots, as these lots are often not used at night but are designed to encourage commuters to transfer from a single occupant vehicle to carpool, bus, or rail (NCTCOG, 2018). Kuttner (2016) suggested this practice for Massachusetts, explaining that although regulations at that time would allow truckers to use these lots for the required 10-hour break, few locations have appropriate striping. When contacted, the author also explained that although the use of these lots at present by trucks had not been studied, he was not aware of truck drivers using the lots for rest purposes (B. Kuttner, personal communication, January 26, 2022).

Implementation Example

Although an occupancy study of specific lots can show deficiencies, another approach suitable at the regional level is to examine counties and municipalities that may have their own regulations. Figure 5 shows the results of an effort to identify city, county, and town restrictions on truck parking based on Virginia's 95 counties, 38 cities, and 49 of its 191 towns. Although roughly one-half (47%) of the sampled localities had no or minor restrictions (e.g., Campbell County prohibited large truck parking on county lots), 30% restricted parking in residential areas (e.g., Pulaski County prohibited parking in areas zoned R-1 or R-2), 6% prohibited parking on some streets (e.g., secondary roads in the Isle of Wight County), 12% prohibited any form of overnight parking (e.g., midnight to 6 a.m. in the City of Staunton), and 5% prohibited most or all truck parking for the purpose of rest (e.g., Henrico County prohibited such parking unless the vehicle was being used for "loading, unloading, or working" (Gidley, 2021; Henrico County, 2022). Towns may have separate truck parking rules from counties. For example, of 49 sampled towns, 10 had the same truck parking regulations as the surrounding county, 4 had similar regulations, and 35 had different regulations. Figure 6 shows how truck parking restrictions can vary between counties and towns and, thus, potentially affect needs for staging prior to deliveries.

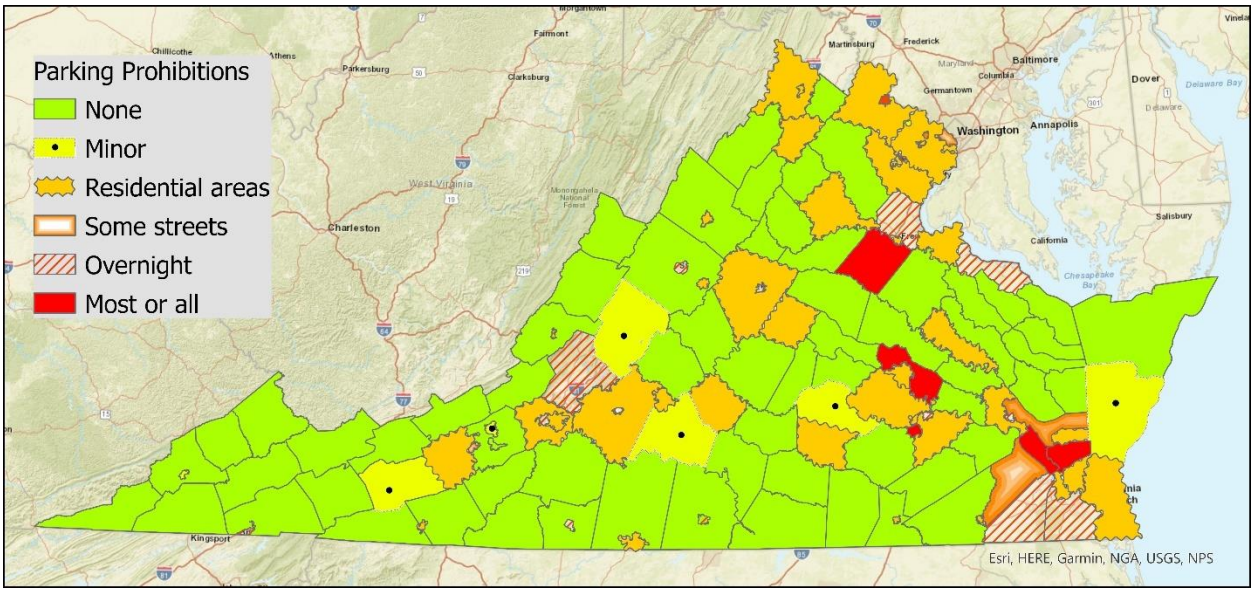

Figure 5. Truck Parking Restrictions by Locality in Virginia (Excluding Most Towns). Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri.

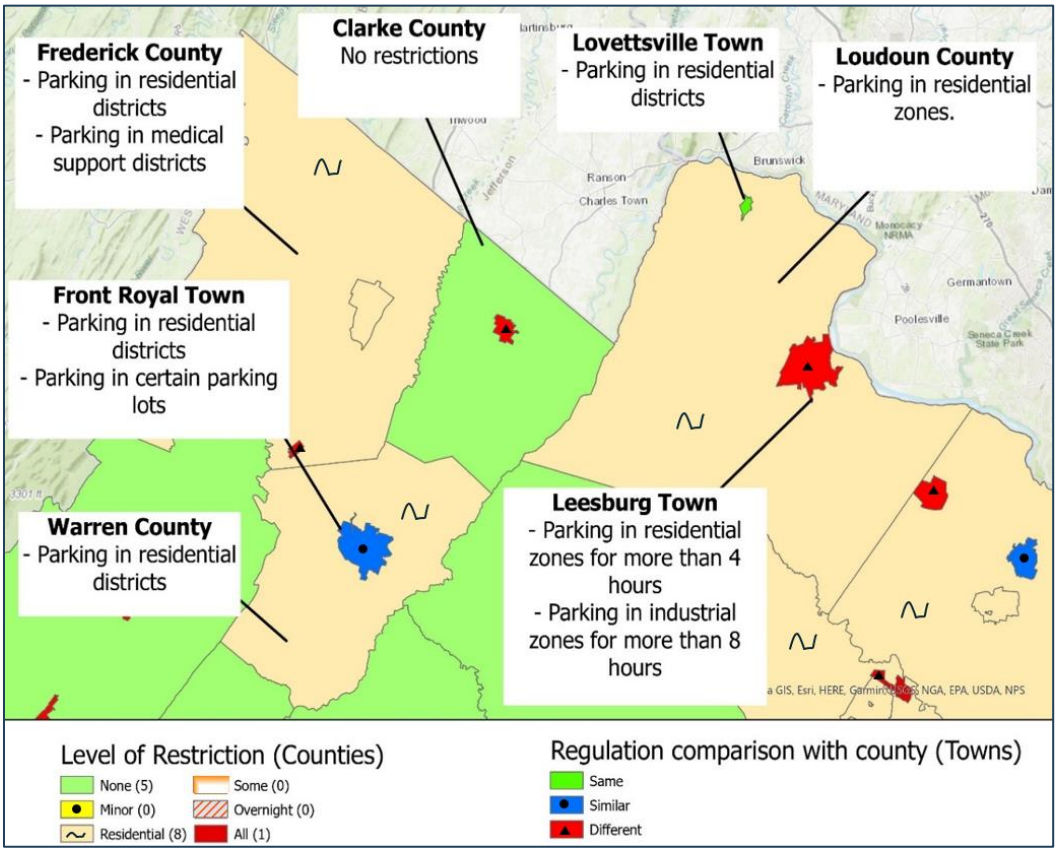

Figure 6. Example of Differences in Truck Parking Restrictions in Counties and Towns in Virginia. Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri.

Although most localities appear to show few restrictions, unmet demand for truck parking may be fairly large. A representative of the Town of Leesburg, which prohibited all truck parking in residential areas and limited parking to 8 hours in industrial districts, noted that if a driver needs to rest to meet a 10-hour rest requirement, the 8-hour restriction will not suffice (Winkler, 2021). In this case, no nearby truck stops leaving commercial vehicle operators, whose destination was in the Leesburg area, no place to park and rest exacerbated the problem. Larger truck stops, located in areas such as Bealeton (Routes 29 and 17), along I–81 to the west or I–70 to the north, tended to be located 2 hours from the town. Thus, seemingly small areas of truck restrictions may portend a larger need for additional truck parking. Knowing such truck parking deficiencies may help planners evaluate potential solutions such as developing a facility that is shared by multiple private entities or creating tax incentives for private truck parking facilities (Phelan et al., 2017).

Studying Truck Routing

Overview

Gunes et al. (2021) found that the use of a freight and transit lane successfully improved truck movements. In a two-block section of lanes traditionally reserved for transit along State Route 99 in Seattle, 1 week of data showed that the allowance of trucks was successful because freight carriers and passenger buses used the lane "at complementary times," leading the authors to suggest that this change in lane use strategy may improve freight movements without adversely affecting transit.

Dong et al. (2019) used the StreetLight Insight platform to determine whether trucks were deviating from truck routes in New York City, i.e., if a truck route was available, how often (and where) were trucks using non-truck routes. The authors used this information to identify the reasons for these deviations and countermeasures. Examples were gaps in the truck network (in which case an approach would be to expand the truck network); the use of non-truck routes to complete local deliveries (in which case defining a more specialized set of routes suitable for local deliveries was an option); and severe congestion (in which case a variety of congestion mitigation measures are possible, including retiming deliveries). Although the StreetLight Insight platform defines "heavy trucks" as being in excess of 26,000 pounds and "medium trucks" as between 14,000 and 26,000 pounds (Abuzayd, 2020), Mendes (2022) pointed out that Dong et al. (2019) found in purchased commercial truck GPS data a similar pattern of truck activity (tractor trailers versus single unit trucks).

Implementation Example

Virginia has designated truck routes and routes restricting trucks. Figure 7 shows Northern Virginia's freight network (blue and red lines) and restricted routes (black lines). The remaining roads are not designated truck routes or restricted routes. A road of acute interest to one locality is Route 15, a restricted truck route.

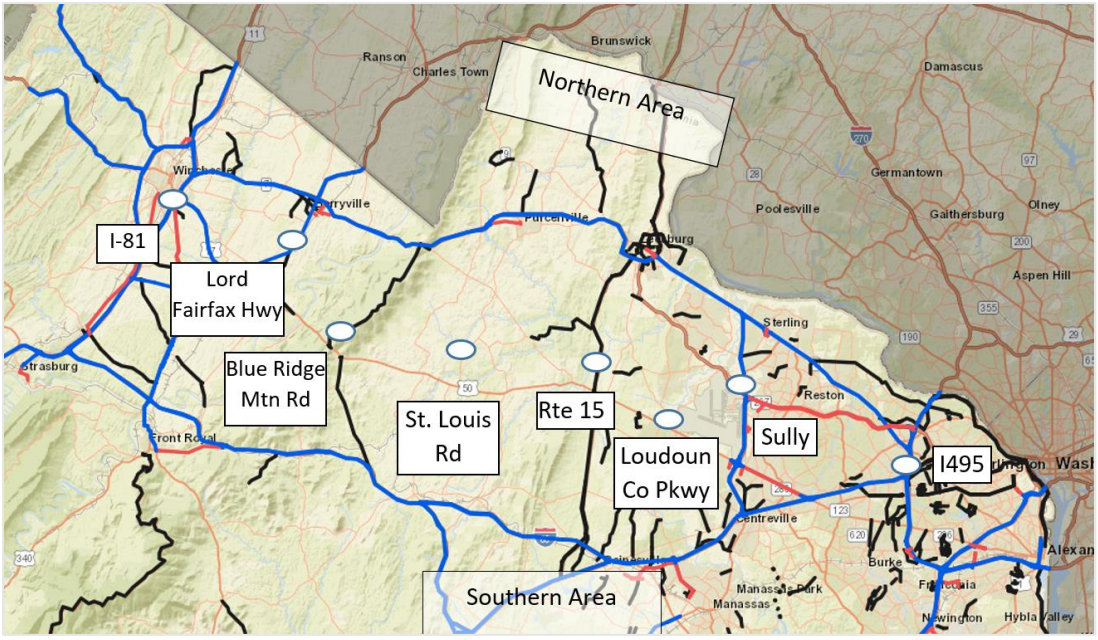

Figure 7. Excerpt of Virginia's Freight Network (blue and red lines) with Restricted Routes (black lines). Blue indicates trucks may travel 1 mile off the roadway for rest or fuel; red does not allow such access. Source: Background map is from VDOT (2021); the research team added modifications.

Figure 8 illustrates the application of the methodology of Dong et al. (2019) used for Route 15: Considered two large areas north and south of Route 15 along with crossing points on designated truck routes, truck-restricted routes, and neutral routes (neither a designated truck route nor a restricted route). Roughly one-half of heavy trucks traversing between the areas used Route 15, with a slightly higher percentage for medium trucks (58%). It is conceivable, but cannot be proven, that the remainder of the truck traffic would benefit from using Route 15 if it were legal (and safe) to do so, especially for those trucks using I–495.

Incorporating Truck Freight into Scenario Planning or Regional Models

Overview

MPOs maintain regional travel demand models, which can support scenario planning. Examples are modifying the location of distribution centers to reduce truck VMT and delay in Puget Sound (Wygonik et al., 2016); quantifying the freight network's ability to continue to operate should links be disabled because of a manmade attack focused on disrupting operations or a natural event such as flooding (Golias et al., 2018); and using origin-destination patterns to determine electric vehicle viability (Jaller et al., 2020). With regard to the latter, Jaller et al. (2020) found that lighter trucks were in greater use because of the "deconsolidation" of port cargo, leading the authors to indicate it was an opportunity to encourage electric vehicles, since limitations of such use were range and capacity.

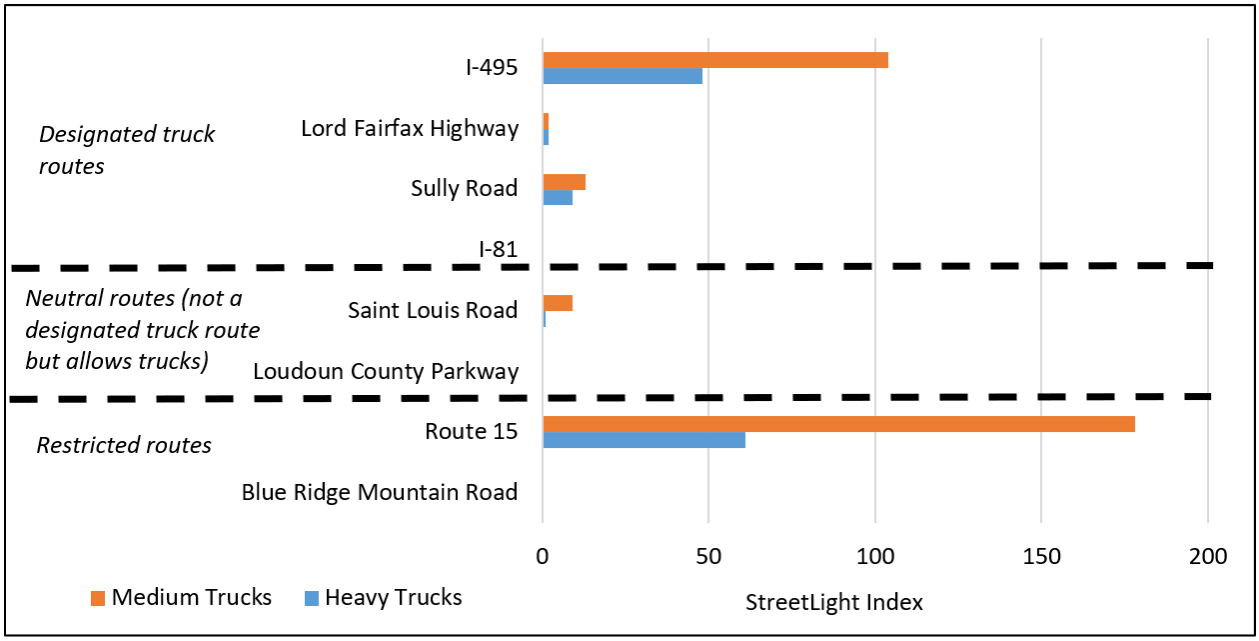

Figure 8. Daily Truck Activity Between Northern and Southern Areas in Figure 7. This activity excludes trips that do not start in one area and terminate in other, along with 8 heavy trucks and 11 medium trucks that used a crossing point other than that shown here. Based on execution of StreetLight Insight platform on January 18, 2022, where the output variable is the StreetLight Index for medium and heavy trucks. Details of truck lengths are not available, so it is possible for some tractor trailer combinations to be less than 65 feet long, which could be permitted on a restricted route.

Although acknowledging a national increase in "medium-duty trucks" and smaller vehicles for making shorter delivery trips, the U.S. Department of Energy (2020) suggests that one region saw such a phenomenon lead to reduction in energy use by between one-fourth and one-half, owing to the fact that moderately longer delivery trips replaced multiple individual "shopping trips." This does not preclude an effort to electrify smaller trucks but may affect how one prioritizes it compared with related initiatives, such as clean energy for transit or incentives for passenger electric vehicles.

Anderson et al. (2011) explained that truck freight trips are typically not part of travel demand models for "smaller communities" and that the failure to account for truck trips may lead to "infrastructure-investment decisions that do not take freight needs into account," such as, presumably, scenario planning analyses. The authors suggested that one way to remedy this deficiency is to apply the *Quick Response Freight Manual*, which gives rates stratified by employment type and truck type. The manual has since been updated, replacing the word "Manual" with the word "Methods" (Beagan et al., 2019).

Implementation Example

Chapter 9 of Beagan et al. (2019) illustrates how to use employment types to develop commodity flows by ton, allocate flows by mode, and then convert the tonnage flows to truck flows. For instance, each agricultural employee is correlated with either 1,146 or 599 truck freight tons annually, depending on the specific type of agricultural employment. Data provided by Woods and Poole (2018) indicated 2,605 agricultural jobs in the region of Virginia's

Harrisonburg City and Rockingham County. Thus, these jobs are expected to be correlated with between 1.56 million and 2.99 million tons of freight generated. Most (86%) commodities in the "other agricultural products" category are shipped by truck, with a rate of 19.36 tons per truck (Beagan et al., 2019). If no other information were available, these rates suggest that regional agricultural employment generates between 69,000 and 133,000 truck trips annually.

Obtaining Freight Data from Public Sources

Overview

Walton et al. (2015) identified 16 public sector responsibilities for which freight-related data are essential, such as understanding the effect of freight shipments on pavement deterioration and the regional economy. Kam et al. (2017) sought to advance this work by showing how to obtain commodity flows from various sources. For instance, most new motor vehicles are transported by rail (long haul) and then by truck (to dealerships). The authors used waybill data coupled with the total number of vehicles produced at Texas auto assembly plants to determine the number of vehicles shipped by rail versus truck. Then, other sources such as the location of dealerships, the location of railroad ramps for loading these automobiles, and population counts helped estimate origin-destination flows for automobiles. Other commodities have different data sources. To estimate timber flows, Kam et al. (2017) defined the origins of the trees harvested (available from the Forest Inventory Data Online database) and destinations of the mills that process these trees (available from a Texas-specific source and the Primary Forest Products Network). The authors then used a gravity model to estimate resultant truck flows.

Implementation Example

To understand truck flows between timber forests and mills, Kam et al.'s (2017) approach was adapted to Brunswick County, Virginia, with a few changes. A key challenge is that although Virginia mill locations are available, exact locations of harvested timber forests are unknown. A representative of Virginia's Department of Forestry provided two statewide pieces of data (Leach, 2022): (1) Mill locations and size categories (small, medium, or large) and (2) total amount of harvested wood by county in 2020. Brunswick County is the largest timber producer in Virginia, accounting for 6% ($18 million) of the total harvested wood value, with three mill facilities in the county at Brodnax, Lawrenceville, and Alberta. These flows from forests to mills are shown in Figure 9.

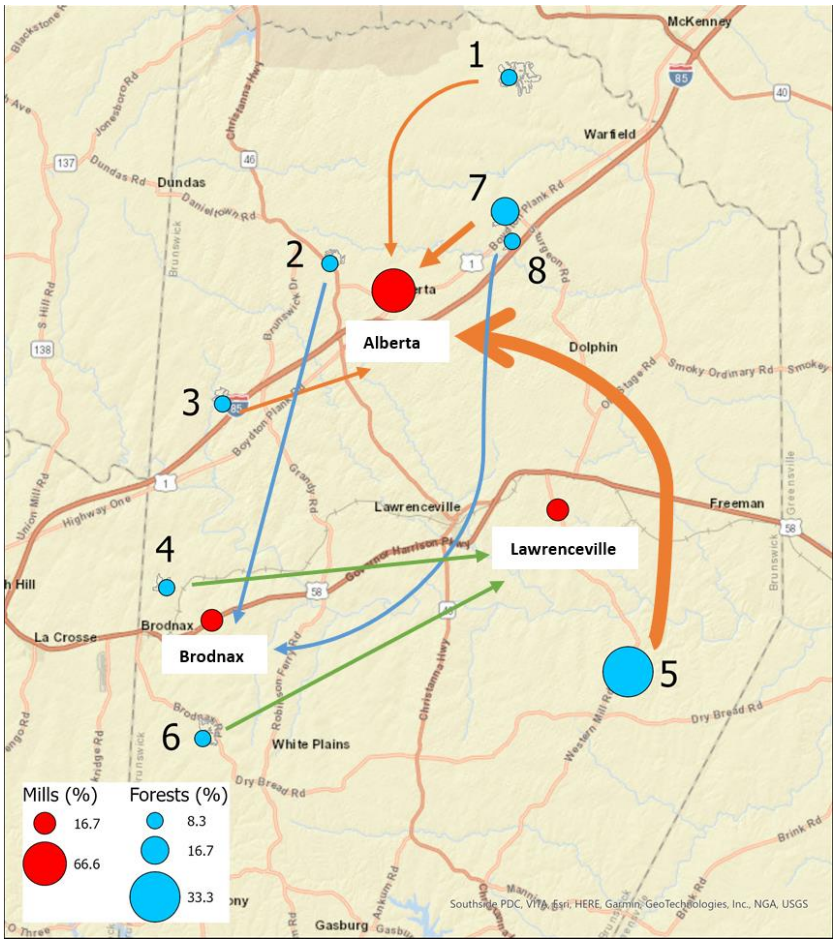

Figure 9. Wood Mills, Forests, and Freight Flows in Brunswick County. An arrow matches each origin with its destination. Widths of forests, mills, and arrows on the map are estimated to be proportional to their StreetLight Index value (a comparative indicator of truck activity). Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri. Base map sources: Southside PDC, VITA, Esri, HERE, Garmin, GeoTechologies, Inc., NGA, USGS.

Land cover data from the Multi-Resolution Land Characteristics Consortium (2022) were used to identify candidate forest locations of at least 75 acres. This threshold was based on an advertisement seeking forests of at least this size (Timber Update LLC, 2022), yielding 543 candidate locations, from which 500 were chosen randomly (because at the time the platform could analyze at most 500 zones simultaneously). The results suggested that for the period from September 2020 through December 2021, truck flows between only eight forests and the three wood mills occurred.

The StreetLight Index, which has been described as giving a "relative volume of trip activity" (Gores, 2022), suggested that the Alberta mill was the leading freight attractor, accounting for about two-thirds of the freight originating from the eight forests. The combination of these sources was crucial both to identify forests that are potentially providing commercial timber and to discern this activity. Figure 9 indicates that the largest activity was from forest 5 to the Alberta mill. These flows do not represent the actual routes, but they can help planners identify likely routes and potential improvements. Of interest is that routes noted on Figure 9

generally align for each forest with only one mill as the destination, and this mill is not always the closest to the forest.

Survey of Virginia PDCs

After trivial responses were removed (e.g., when only the individual's agency was identified), each of Virginia's 21 planning districts had exactly one respondent except that of Northern Virginia (Figure 10). Northern Virginia was replaced with two separate entities that plan for that area because it does not have transportation planning responsibilities—the Northern Virginia Transportation Authority (a suggestion from a representative at the Northern Virginia Planning District who had initially been contacted about the survey) and the Metropolitan Washington Council of Governments (MWCOG). Raw survey data, a more detailed summary, and the survey questions are available as part of the supplemental materials for this report.

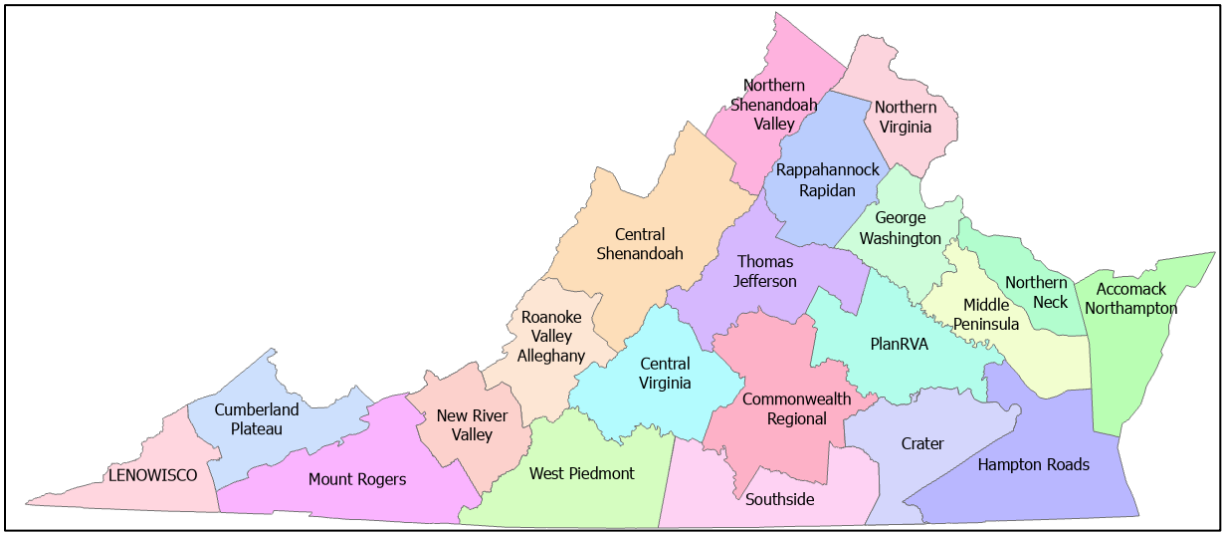

Figure 10. Approximate Boundaries of Virginia's 21 Planning District Commissions. Counties that are part of more than one planning district are kept to just one district to simplify the display. Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri.

Table 2 summarizes the answers of the PDC respondents to the first 50 questions in the survey, with the number of the practice shown in column one, and the abbreviations for the practices shown in column two. (The longer titles for the practices are in appendix A.) For the 22 PDC respondents, the number of respondents that perform the practice are shown in column three. The number of respondents that do not perform the practice but are interested in performing it is shown in columns four through six. Column four shows the number with high interest (e.g., a score of 4 or 5), column five shows the number with medium interest (a score of 3), and column six shows the number with low interest (a score of 1 or 2). Column seven shows the number of respondents who either indicated "Don't know" or left the question blank.

Table 2. Summary of Planning District Commission Responses

No.	Abbreviated Freight Practice	Yes [a]	Level of Interest [b]			Don't Know [c]
			High	Medium	Low	
1	Inventory industrial land uses	1	5	6	7	3
2	Improve forecasting for truck freight	3	4	2	9	4
3	Quantify truck freight in the economy	7	5	3	5	2
4	Innovative truck parking solutions	6	8	2	4	2
5	Truck parking during emergencies	1	11	1	6	3
6	Safety analysis for truck freight	3	7	2	6	4
7	Evaluations of truck parking technologies	1	4	4	11	2
8	Regional freight advisory committee	4	7	2	6	3
9	Short-term physical improvements from private sector	3	8	5	4	2
10	Short-term operational improvements from the private sector	4	7	5	4	2
11	Longer-term needs from the private sector	7	6	3	4	2
12	Restrictions on freight deliveries	2	6	1	11	2
13	Criteria for future deliveries	0	4	4	11	3
14	Examination of ways warehouse locations affect VMT and delay	3	5	3	8	3
15	Examination of ways shorter truck trips may support electric trucks	0	8	3	9	2
16	Coordination of land use planning and truck freight planning	3	6	5	5	3
17	Scenario analysis for truck freight planning	4	4	0	10	4
18	Coordination of state and local growth planning	5	6	5	5	1
19	Identification of network gaps from truck restrictions	4	5	2	8	3
20	Identification of network gaps from missing links	4	6	3	5	4
21	Identification of network gaps from geometric deficiencies	4	7	1	7	3
22	Identification of network gaps from lack of resiliency	5	9	1	5	2
23	Identification network gaps from limited capacity	5	8	2	6	1
24	Truck trips not using truck routes	2	6	4	8	2
25	Innovative engineering treatments for trucks	1	2	5	11	3
26	Freight flows from public data sources	8	5	4	4	1
27	Freight performance computations	6	5	5	5	1
28	Identification of truck bottleneck locations	8	3	6	4	1
29	Engineering treatments at truck bottleneck locations	3	5	5	8	1
30	Locations where freight traffic is limited by capacity	4	5	4	8	1
31	A single location for urban deliveries	0	2	2	13	5
32	Freight consolidation centers	0	3	2	11	6
33	Low bridges affecting deliveries (business)	5	6	1	8	2
34	Load-restricted bridges affecting deliveries (business)	4	7	3	6	2
35	Geometric restrictions affecting deliveries (business)	4	7	4	5	2
36	Low bridges affecting deliveries (military)	2	4	1	13	2
37	Load-restricted bridges affecting deliveries (military)	2	3	1	14	2
38	Geometric restrictions affecting deliveries (military)	1	4	1	14	2
39	Truck toll feasibility studies	1	1	2	14	4
40	Truck variable tolling feasibility studies	0	1	2	15	4
41	Truck toll pricing studies	1	0	1	16	4
42	Goods movement action plan	0	4	6	8	4
43	Freight project evaluations (reduced truck hours of delay)	6	4	4	5	3
44	Freight project evaluations (improved reliability)	5	5	4	5	3
45	Ways to implement freight in project prioritization	6	4	5	4	3
46	Incorporation of truck parking needs as part of zoning ordinances	0	7	5	7	3
47	Providing county, stadium, or mall lots to provide truck parking	0	4	10	6	2
48	Designating truck-only parking on certain streets	0	4	7	8	3
49	Locally funded truck parking areas	0	5	4	9	4
50	Hazardous materials movements	3	4	6	7	2
Mean		3.0	5.1	3.4	7.8	2.6

VMT = vehicle miles traveled.

[a] YES = agency does the practice at present.

[b] Level of Interest = agency does not perform the practice at present.

[c] Don't know = respondent does not know if the practice was performed or left the question blank.

For example, practice 1 may be considered. The full question on the survey was "Does your agency conduct an inventory of industrial land uses for the purposes of preservation through zoning ordinances, redevelopment efforts, or tax credits?" Table 2 abbreviates practice 1 as "inventory industrial land uses." Of the 22 PDC respondents, 1 does the practice, 18 do not, and 3 either indicated "don't know" or left the question blank. Of the 18 that do not do the practice, 5 had "high interest" and 7 had "low interest."

Similarities Among Respondents

Most of the PDCs do not conduct any of the practices; the average number of respondents who perform each practice was 3.0 (of 22 respondents). The most frequently performed practices were determining freight flows from public data sources and identification of truck bottleneck locations (8 of the 22 respondents), followed by identifying longer term needs based on private sector input and quantifying the importance of truck freight in the regional economy (each with 7 of the 22 respondents). Ten practices, such as investigate the use of designating truck-only parking on certain streets, developing a goods movement action plan, or locally funded truck parking areas, are not performed by any PDCs.

When considering practices not undertaken but of high interest (score of 4 or 5 out of 5), no practice interested all PDCs. The practice with the highest interest was identifying options for truck parking during emergencies (11 PDCs), followed by identification of critical gaps in the truck freight network based on lack of resiliency (9 PDCs). Four other practices had a high level of interest for eight respondents: identification of innovative truck parking solutions, identification of critical gaps in the truck freight network based on limited capacity, identification of needed short-term physical improvements based on input from the private sector, and examining how an increase in shorter truck trips may be an opportunity to introduce electric trucks.

More practices had low interest than high interest: the average number of respondents reporting low interest (score of 1 or 2 out of 5) for each practice was 7.8 compared with an average of 5.1 reporting high interest. The practices with the most respondents in the low interest category in Table 2 included those that related to tolling and the military (e.g., load-restricted bridges that affect deliveries to the military) and a single location for urban deliveries.

An average of 2.6 respondents (of 22) responded "Don't know" for the practices. For each of the 50 practices, there was at least one "Don't know" response. The two practices with the most such responses were to investigate freight consolidation centers to reduce urban last truck VMT and work with private businesses to have a single location for deliveries within a particular urban area.

Differences Among Respondents

The lack of interest in some practices may be partially attributed to heterogeneity among the PDCs. For instance, seven PDCs where highly interested in the practice of incorporating truck parking into zoning ordinances—but another seven respondents expressed little interest. Of the seven who indicated little interest, four were from fairly urban locations (Northern Virginia's

two respondents, George Washington [which includes Fredericksburg Area Metropolitan Planning Organization], and the Tri-Cities), and three were from rural locations (Lenowisco, Cumberland Plateau, and Central Shenandoah). That said, in a free response section, one respondent from the Middle Peninsula PDC noted that the survey should refocus on rural areas:

> Many of the questions and planning/study ideas included in the survey were mostly relevant for MPOs and urban localities. Consider engaging the rural localities/PDCs with a survey customized to meet the local transportation network playing field, i.e., rural localities rely on VDOT for many of the questions asked.

This thought was echoed by a second respondent who said one should differentiate between urban and rural regions.

Other practices shown in Figure 11 showed the level of interest was divided. For example, eight PDCs have low interest in practice 33, which is identifying low bridges that affect deliveries to and from businesses. However, six PDCs have a high interest in this practice, and another five PDCs perform this practice.

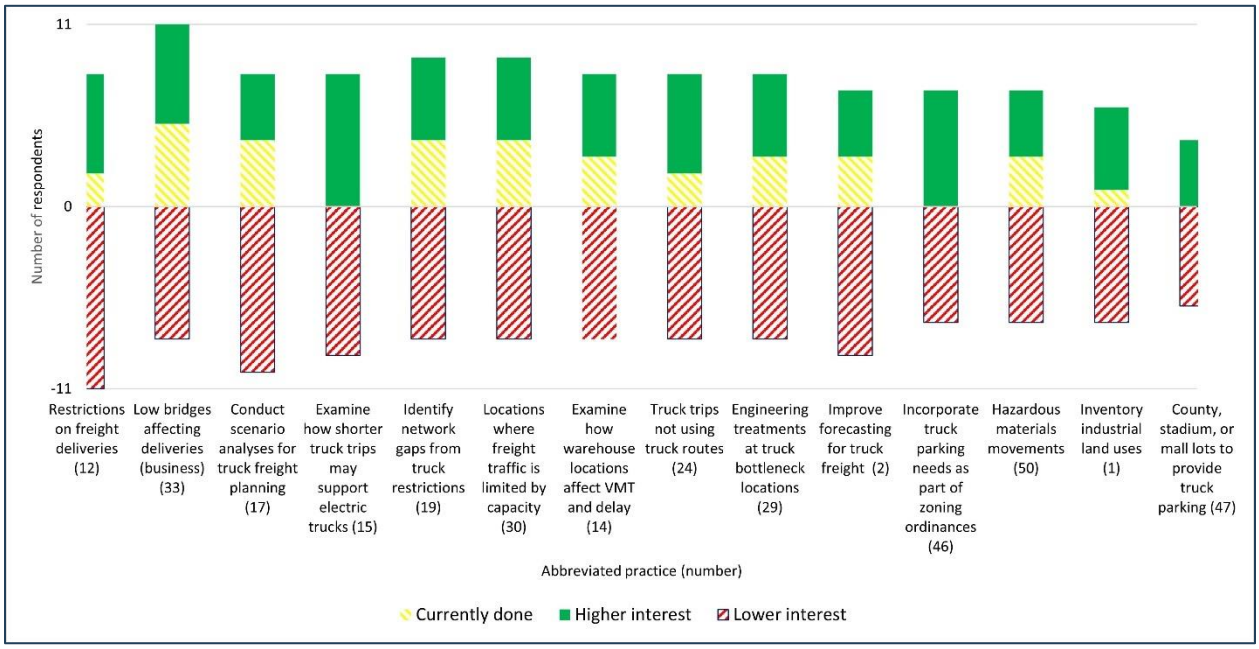

Figure 11. Examples of Practices for Which Level of Interest Diverges by PDC

Figure 12 shows the number of practices with a high level of interest by PDC. For example, Northern Shenandoah Valley has a high level of interest in 21 practices. The colors in the map indicate the number of practices performed by the PDC; for example, because the Northern Shenandoah Valley is performing four practices (identify any low bridges that affect deliveries to and from businesses; evaluate freight projects based on the economic benefit of reducing truck hours of delay; evaluate freight projects based on the economic benefit of improving reliability; and implement ways to consider freight in project prioritization), the color for that PDC is gray.

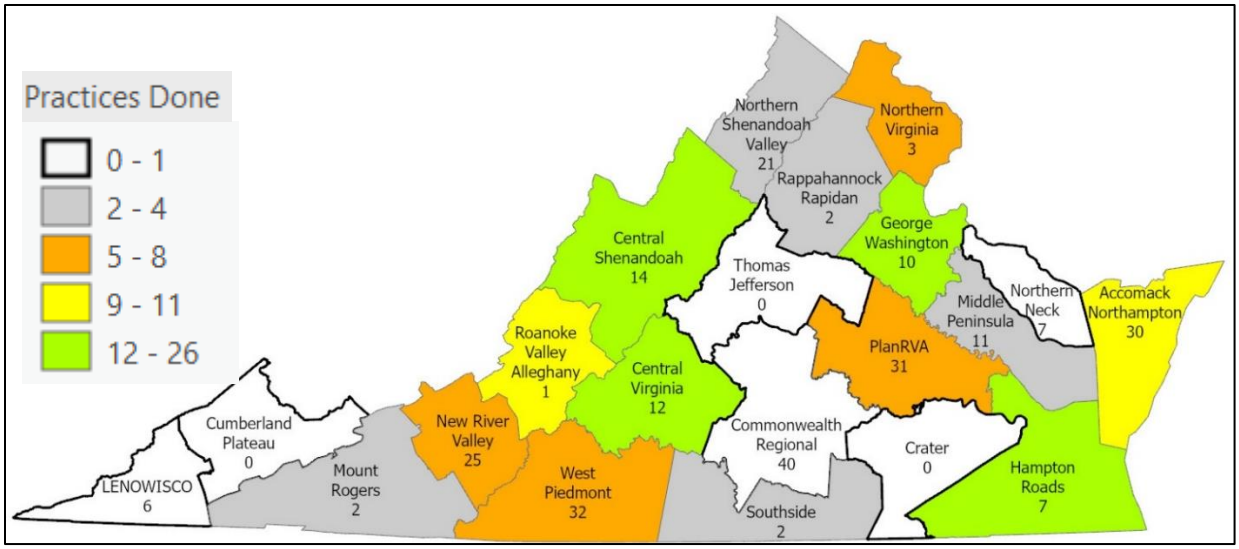

Figure 12. Practices Performed by PDC Respondents (colors) and High Interest in Performing the Practice by PDC Respondents (labels). For example, Hampton Roads PDC in southeast Virginia performs 26 practices (hence, it is green) and has a high level of interest in another 7 practices. Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri.

On average, a PDC has a high level of interest in 11.6 of the 50 practices. However, this average masks a wide range by PDC. Some respondents were interested in many practices (such as Commonwealth Regional Council, West Piedmont, or Accomack Northampton), whereas others were interested in none (Cumberland Plateau) or responded, "Don't know" (Thomas Jefferson). Northern Virginia had two respondents. The Northern Virginia Transportation Authority indicated a high level of interest in three practices, and MWCOG did not indicate a high level of interest in any practice. Northern Virginia Transportation Authority responded that no practices are performed, but MWCOG noted that six are performed, so orange was assigned for that region in Figure 12.

Question 51 asked respondents if other practices, besides those mentioned in the survey, would improve freight planning in Virginia. In addition to the rural-urban divided focus that two respondents noted, three practices showed unique factors specific to each PDC:

- *Include other truck categories; trucks are not just 18 wheelers.* The PlanRVA respondent noted that in the travel demand model, one should include category five trucks (single unit two-axle trucks) as medium trucks, rather than as passenger vehicles. The Lenowisco PDC respondent noted that in that region, one needs to focus on local freight such as mineral mining, farming, and construction trucks, rather than just tractor trailers.
- *Examine the impact of trucks with respect to [land] development such as major distribution centers and activity centers*, as the Crater PDC respondent suggested.
- *Have VDOT fund freight-related planning studies through the PDCs* as the Commonwealth Regional Council suggested.

Potential Initiatives

The result of the survey suggests three opportunities to leverage PDC freight interests: showcasing best practices, conducting more detailed studies, and holding longer term PDC and VDOT information exchanges.

Opportunities to Showcase Best Practices

Question 52 asked if there were particular practices an agency uses that they would be willing to showcase so that others in Virginia could apply those practices. When these responses are combined with other information, they show at least four areas where PDCs could share their experiences with others.

- *Project prioritization in rural and urban areas.* The Middle Peninsula PDC has initiated a process to identify transportation improvement projects that best align with the priorities of available funding sources. The Heartland Regional Transportation Planning Organization noted also that it incorporates freight into the regional Project Prioritization Process. Related to this topic, the George Washington Regional Commission suggested that a practice to improve freight planning could be to investigate freight delays as a metric to fund SMART SCALE projects.
- *Trends development.* PlanRVA, which includes the Richmond Regional Transportation Planning Organization, identified 17 districts within the PDC that are used to understand truck flows between those districts. The respondent also noted the use of StreetLight Insight® data to forecast truck volumes. Only one VDOT respondent named a practice in in answering question 52, stating that VDOT collects some truck data "but not to the level that the questions required."
- *Freight Advisory Committee.* The Hampton Roads Planning District Commission noted the use of its active Freight Transportation Advisory Committee, which assists with the regional transportation planning process and its preparation of a Regional Freight Study. Four respondents indicated they already do this practice (Central Shenandoah, MWCOG, Accomack-Northampton, and Hampton Roads Planning District Commission) and seven respondents indicated they do not do this practice but would be highly interested (score of 4 or 5 out of 5): Commonwealth Regional Council, PlanRVA, George Washington Region PDC, Central Virginia, West Piedmont, Northern Virginia Transportation Authority, and New River Valley).
- *Information Exchange for Rural and Urban Areas.* The Accomack-Northampton PDC noted it did not have a practice to showcase but responded that it would be interested in learning from other rural, high freight areas in Virginia. The Middle Peninsula Planning District Commission's observation that the survey should be redone to target rural areas also supports a rural information exchange, as does Lenowisco's suggestion that regional freight should focus not only on tractor trailers but also on mineral, farming, and construction trucks. A counterpart to the rural focus could be an information exchange for urban areas, given MWCOG's response (which includes Northern Virginia), where a regional freight plan is under development along with a regional air systems plan that has a separate air cargo element.

Potential Future Detailed Studies

The survey responses suggested at least two possibilities for a freight-oriented initiative that might be of interest to the PDCs and informative for VDOT. Table 3 shows the PDCs expressing a high interest in various truck-parking related practices and a few that noted they already perform the practice. Note that except for Southside, most of the PDCs expressing an interest in practice 46 also expressed an interest in at least one other parking-related practice.

Table 3. PDCs with a High Level of Interest in Certain Practices Related to Truck Parking

Short Name for the PDC	Innovative Truck Parking Solutions (4)[a]	Evaluation of Truck Parking Technologies (7)[a]	Incorporation of Truck Parking Needs as Part of Zoning Ordinances (46)[a]	County Stadium, or Mall Lots to Provide Truck Parking (47)[a]	Designation of Truck-Only Parking on Certain Streets (48)[a]	Locally Funded Truck Parking Areas (49)[a]	Truck Parking During Emergencies (5)[a]
Lenowisco	√						√
Mount Rogers			√			√	
New River Valley	X		√				√
Central Shenandoah	√						√
Northern Shenandoah	√	√	√	√	√	√	√
Central Virginia	X	√	√	√	√	√	√
West Piedmont	√			√	√	√	√
Southside			√				
Common-wealth Regional	√		√	√	√	√	√
PlanRVA	√	√	√				√
George Washington	X	X					√
Middle Peninsula	X						√
Accomack	√	√					
Hampton Roads	√						√

PDC = planning district commission.

[a] Practice number. √ indicates a highly interested PDC (4 or 5) in implementing the practice; X indicates PDC already performs the practice.

- *Identify options for truck parking during emergencies (practice 5).* One-half of the PDC respondents (11 of 22) have a high level of interest in this practice compared with 6 that have a low interest, suggesting that a case study could focus on the Middle Peninsula and George Washington PDCs, both of which indicated a high level of interest. Middle Peninsula remarked about the benefits of considering the needs of rural PDCs, which could be a shorter term need (e.g., identify truck parking needs now).

- *Incorporate truck parking needs as part of zoning ordinances when sites are developed (practice 46).* About one-third (7 of 22) of PDCs have a high interest in this practice compared with 7 with a low interest. Of the 7 with a high interest, 6 are largely rural. (Figure 13.) This practice could be a medium-term need and would entail cooperation with city or county officials responsible for zoning decisions.

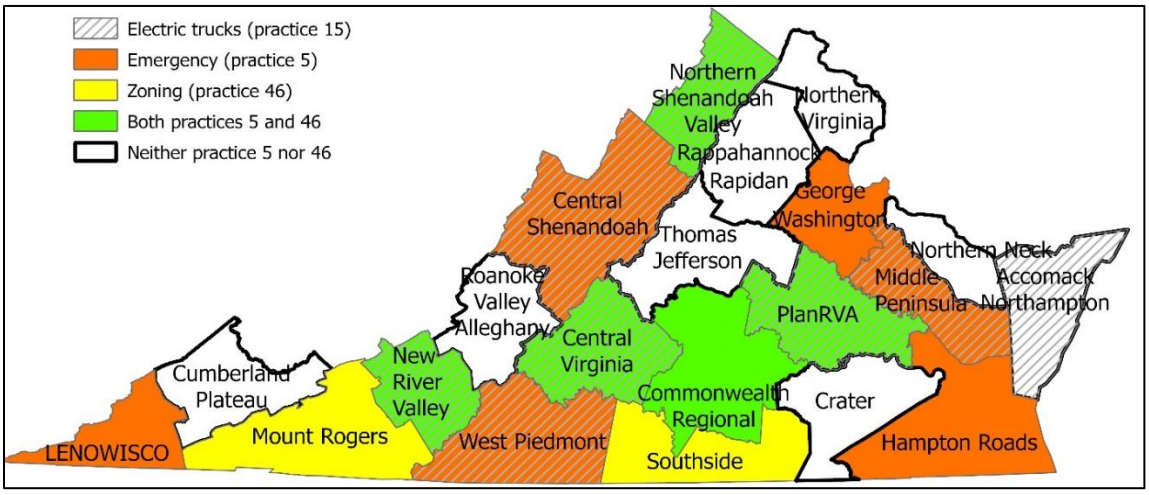

Figure 13. PDCs Expressing a High Level of Interest in Practice 5 (truck parking during emergencies) Practice 46 (incorporation of truck parking into zoning ordinances) and Practice 15 (electric trucks). Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri.

Information Exchange Between PDCs and VDOT

The supplemental materials associated with this report show that the same survey distributed to the 22 PDCs was also distributed to the VDOT districts. The research team received responses for eight of VDOT's nine districts, with two districts each having two separate responses. Although the VDOT respondents indicated they perform practices that are oriented toward roadway design (e.g., identification of network gaps), the respondents also indicated some practices outside the sphere of roadway design as being practiced: coordinate land use planning and truck freight planning (6 of the 10 respondents), the use of regional FACs (5 respondents), and restrictions on freight deliveries (5 of the 10 respondents).

These responses showed that some practices are of relatively high interest to PDCs but not implemented by PDCs and are being implemented by VDOT. For example, 7 of the 22 PDC respondents indicated they are interested (but not implementing) load restricted bridges affecting deliveries (indicating a high interest), and 6 of the 10 VDOT respondents indicated they are implementing this practice. Such a practice may be an opportunity for an exchange information between VDOT and PDCs. In fact, one response to question 51, "Do you have suggestions for other practices not mentioned in this survey to advance freight-related planning in Virginia? (Please describe)," from the VDOT Hampton Roads respondent was that VDOT and PDCs should continue sharing information. The following are four other such practices PDCs and VDOT conducted:

- Innovative truck parking solutions (practice 4). This practice is of high interest but not done by 8 of the 22 PDC respondents and performed by 7 of the 10 VDOT respondents.
- Safety analyses for truck freight (practice 6). This practice is of high interest but not performed by 7 of the 22 PDC respondents and was performed by 7 of the 10 VDOT respondents.
- Identify short-term physical improvements from the private sector (practice 9). This practice is of high interest but not implemented by 8 of the 22 PDC respondents and performed by 5 of the 10 VDOT respondents.
- Load-restricted bridges affecting deliveries for businesses (practice 34). This practice was of high interest but not performed by 7 of the 22 PDC respondents but was performed by 6 of the 10 VDOT respondents.

Conduct the Pilot Case Study

Goal of the Pilot Effort

The survey showed that several PDCs were interested in a practice of incorporating truck freight needs into zoning practices, and NSVRC was invited to participate in this pilot effort. In response to a presentation of this practice to an NSVRC technical advisory committee meeting in January, NSVRC noted it was potentially interested in a pilot effort but had some suggestions for changing the scope. These suggestions were to (1) determine if truck patterns in the region had changed since the onset of the pandemic; (2) determine the extent to which local freight-related land uses, primarily in the industrial category, might increase truck parking demand at various distances (say 20, 50, and 150 miles away) from the site but does not focus on parking needs at the site; and (3) focus on one county in particular that was a willing partner in this effort (Warren), clarifying that the pilot is for informational purposes only. In June, participants pointed out that the pilot should look at forecasts of ways truck parking demand might change during the next 20 years and compare two sources of demand—truck parking driven by land use changes and truck parking driven by the fact that I–81 is a through corridor. Then in August and September, the scope focused on how this information could support the county's comprehensive plan. Table 4 summarizes how the scope evolved during this pilot effort.

Table 4. Summary of Key Decisions During the Pilot Effort

Date	Event	Key Results
January 5	Virtual meeting with the Metropolitan Planning Organization Technical Advisory Committee. Present summary of planning district commission (PDC) survey and propose pilot to incorporate freight into zoning.	• The PDC might be interested in piloting the practice, depending on local interest and modifications to scope. • A longer followup meeting will be held to discuss further.
February 6	Virtual meeting with Brandon Davis, Amanda Kerns, and John Madera of Northern Shenandoah Valley Regional Commission (NSVRC), Barbara Nelson of Virginia Port Authority (VPA), and Erik Johnson and Shane McCabe of VDOT.	• The purpose is to document the need for additional truck parking, given local freight-related land uses. • The scope should focus on Warren County—a willing partner.
February 20	In-person meeting at NSVRC to discuss a revised scope of work.	• The pilot does not mean Warren County necessarily wants additional truck parking. This pilot estimates the demand for parking. • If time permits, use StreetLight Insight to look at where trucks are stopping after they leave the Inland Port and compare the results with John Madera's earlier work. • Use OnTheMap (U.S. Census Bureau, n.d.) to estimate generators of truck trips (and comp with the data Taryn Logan of Warren County provided).
March 1	Phone call with Erik Johnson.	• Send John Madera a map of Warren County and ask where truck parking problems are located. John responded they are on the Walmart/Riverton Commons in the northeast quadrant of the I–66-Route 340-Route 522 interchange.
March 17	Meeting with Erik Johnson to discuss the revised scope.	• John Miller and Nishara will send a revised scope based on the meeting and earlier material. • Erik will provide some additional information.
March 24	Meeting with John Madera at 3 pm to discuss StreetLight interpretation.	• Definitely use a grid analysis for StreetLight Insight. • Compare 2019 and 2021 data.
June 6	Virtual meeting with Erik Johnson (TMPD), Barbara Nelson (VPA), Taryn Logan (Warren County), and Shane McCabe (VDOT Staunton District) to discuss a methodology for measuring truck parking generated by existing Warren County industries based on the Federal Highway Administration (FHWA) estimation tool.	• The demand given is for 2020. Present these results for forecast years based on future forecasts of employment by North American Industry Classification System code in Warren County. • The demand given reflects only freight generated by Warren County. It does not account, for example, for the fact that I–81 (a multistate corridor) is also generating demand for truck parking. Examine the "report card" available for existing truck facilities showing the facilities that are overburdened.

Date	Event	Key Results
June 8	Meet with Erik Johnson to take advantage of VDOT's truck freight study.	• Use a shapefile of updated truck facilities from the Virginia truck study to complement the FHWA data. • Recognize that the forecasted growth rate at truck facilities (e.g., 1%) is based on historical trends. • Examine the Northern Shenandoah Valley Region for evidence of truck parking through the use of aerial imagery.
August 10	Virtual meeting with Taryn Logan (moved to NSVRC), Matt Wendling (Warren County), Shane McCabe (VDOT Staunton District), Barbara Nelson (Virginia Port Authority), Erik Johnson (VDOT TMPD).	• The researchers shared draft geographic information system maps showing parking demand with Matt Wendling, who requested these maps. • Because a truck space during a 24-hour period can accommodate more than one truck if trucks stop for less than that period, the research team should find some way of converting truck stops to truck spaces. • This type of work can be included within the comprehensive local plan for interested localities to encourage adequate parking. • A future research need is to determine if rest areas can accommodate charging needs for electric trucks (also noted on June 6th). • Determine if the FHWA truck parking tool is exclusively for tractor trailers.
September 7	Email and phone call with Matt Wendling regarding possible language that localities could, at their choosing, use in a comprehensive county plan.	• Specific language suggested by the representative should focus on the "Implementation" section of the plan. • Language should encourage parking when site plans or rezonings occur. • Maps of truck parking facilities can support this endeavor.

TMPD = Transportation Mobility Planning Division.

In sum, the pilot had three deliverables:

- Quantify the extent to which truck patterns have changed since the pandemic (2019 versus 2021).
- Forecast truck parking demand for 2045 based on local land use changes.
- Forecast truck parking demand for 2045 based on through traffic.

Extent to Which Truck Patterns Have Changed Since the Pandemic (2019 versus 2021)

NSVRC had previously used the StreetLight Insight platform, where an origin-destination and a "Top Route for Zone" technique determined the counties that were truck freight destinations and the major routes serving those counties, all for truck freight originating from the Virginia Inland Port—a major economic generator in Warren County (NSVRC, 2016). NSVRC was interested in knowing if these patterns had changed since 2019. At the time of the pilot (March 2023), the most recent dataset that was available with the StreetLight truck index was for

2021. Thus, the researchers did the analysis in March 2023 and compared the more recent 2021 results with the earlier 2019 data originally analyzed by NSVRC.

The origin-destination analysis results suggested that truck patterns were consistent from 2019 to 2021, with the highest destination (Warren County) having the highest share (37.13%) of all trips originating at the Virginia Inland Port compared with 37.02% after the onset of the pandemic (Figure 14), based on the StreetLight truck index (Reddy, 2023). Some counties exhibited modest changes (e.g., almost 9% of trips from the Port were destined for Frederick County in 2019, with this percentage dropping to roughly 8% in 2021). This consistency is observed whether one uses only the Virginia Inland Port as the origin (as done in Figure 14) or all of Warren County. For instance, for all truck trips originating in Warren County, 39.46% stopped in Warren in 2019 compared with 41.46% in 2021.

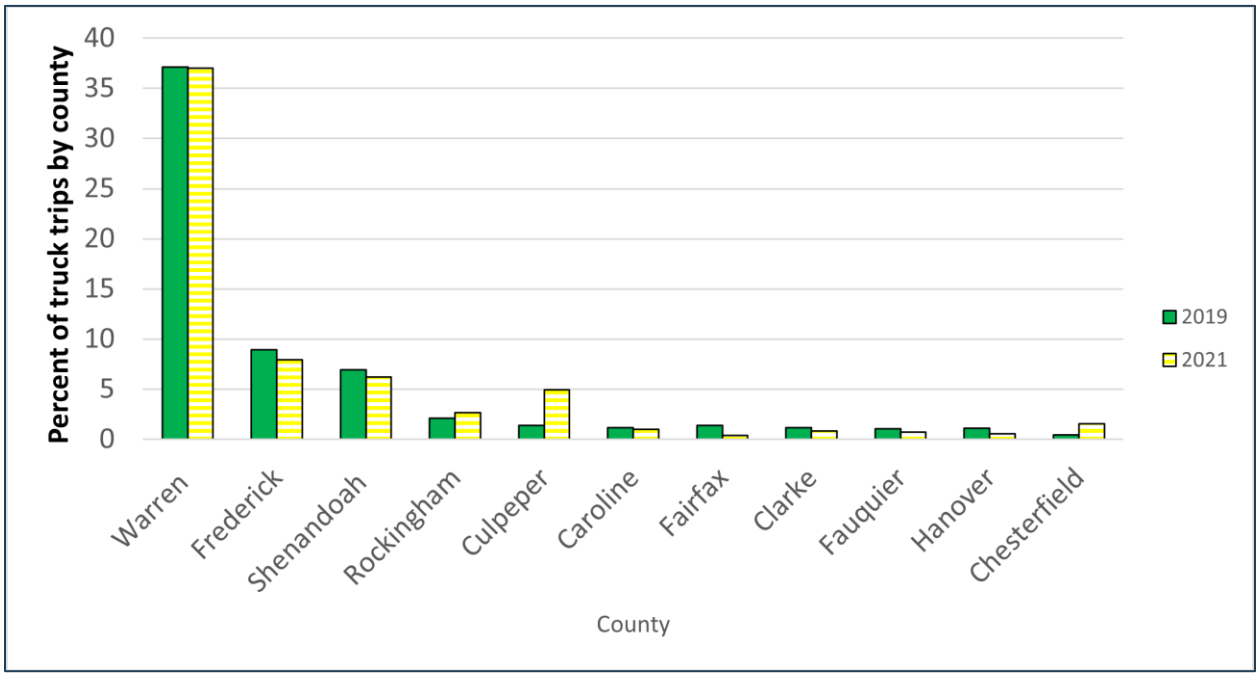

Figure 14. Percent of Truck Trips Originating at the Virginia Inland Port and Terminating in Virginia Counties. For instance, slightly more than 1% of truck trips originating from the Port terminated in Culpeper County in 2019, with this figure climbing to almost 5% in 2021.

Another example of patterns remaining relatively consistent relates to Stonewall Industrial Park, a key destination for deliveries from the Virginia Inland Port (John Madera, personal communication, March 24, 2023). In 2019, roughly 27% of the truck trips originating from the Port were using I–81 Northbound just south of the park, and in 2021, the share was similar but with a modest increase to 31%.

Forecast of Offsite Truck Parking Demand Based on Local Employment Growth

Observed employment for a base year of 2020 and forecast employment for a future year of 2045 for freight-intensive industries (Holguín-Veras et al., 2017) was obtained from Woods and Poole (2023) for Warren County (Table 5). Then, FHWA's truck parking estimation tool (Dowell et al., 2022; Julien 2023a) was used to estimate the number of truck parking spaces

needed within various driving distances of freight generators and reflect multiple types of parking needs such as long-term parking for rest, short-term parking for staging, and federally required half-hour rest breaks. Although the tool does not explicitly differentiate among truck types (e.g., box trucks could be conceivably used for deliveries), Julien (2023b) explains that the focus is tractor trailers.

Table 5. Employment Generated from Freight-Intensive Industries in Warren County (Woods and Poole, 2023)

NAICS Code	Freight-Intensive Industry	2020 Employment	2045 Employment
23	Construction	1,467	1,369
31–33	Manufacturing	1,177	1,276
42	Wholesale trade	250	330
44–45	Retail trade	2,197	2,119
48–49	Transportation and warehousing	1,504	1,566
72	Accommodation and food services	1,263	2,320
All other industries		10,645	15,595
Total employment generated in Warren County		18,503	24,575

NAICS = North American Industrial Classification System.

The tool's results are rough estimates for three reasons: Rates for truck parking for Virginia could differ from those used in the tool, the tool forecasts the number of truck stops but not their duration, and because of an imperfect alignment between the land uses in the tool and land uses in the dataset, some additional processing is required, as appendix B shows. However, the tool gives a high-level way to understand demand for truck parking as a function of employment, for businesses sending or receiving freight, within a given county or city. For instance, for retail trade (North American Industry Classification System [NAICS] 44–45), Table 5 shows a current employment of 2,197 employment sites at various establishments in Warren County. Based on that employment value, the tool estimates that 152 offsite truck parking stops, 20 to 50 driving miles away from Waren County, are needed to accommodate Warren County's employment in the retail trade sector (NAICS 44–45). According to the tool, the same employment sites require 34 offsite truck parking stops located 50 to 150 driving miles away for the year 2020. Stops are not necessarily equivalent to spaces. For instance, if each stop lasted a half an hour, then a single space might accommodate several truck parking stops.

Examination of the roadway network suggests that 1.8 driving miles are equivalent to roughly 1.0 aerial miles, i.e., the 34 offsite truck parking stops reflect an aerial distance of 28 to 83 miles. The 2020 and 2045 demands for truck parking based on the aerial distances of roughly 0.1–11, 11.1–28, 28.1–83 and more than 83 miles from Warren County were determined (Figure 15). Table 6 shows these values. These distances are calculated from the geographic centroid of the county.

Table 6 suggests that parking will need to accommodate an additional 87 stops between 11 and 28 miles from Warren County by the year 2045 than was the case in 2020. As might be expected given the presence of the Virginia Inland Port, the major industry that contributes to the demand for parking is the transportation and warehousing industry.

The data in Table 6 forecast the number of stops per truck. However, participants pointed out that a one-to-one relationship between trucks needing to stop and truck spaces is not necessarily appropriate: Finding 2,203 trucks needing to stop within 11 to 28 miles of the County does not mean one must necessarily have 2,203 spaces. Accordingly, a rough estimate of truck parking duration was based on Dowell et al. (2022) who provided the average duration for truck parking by land use type in Maricopa County, Arizona.

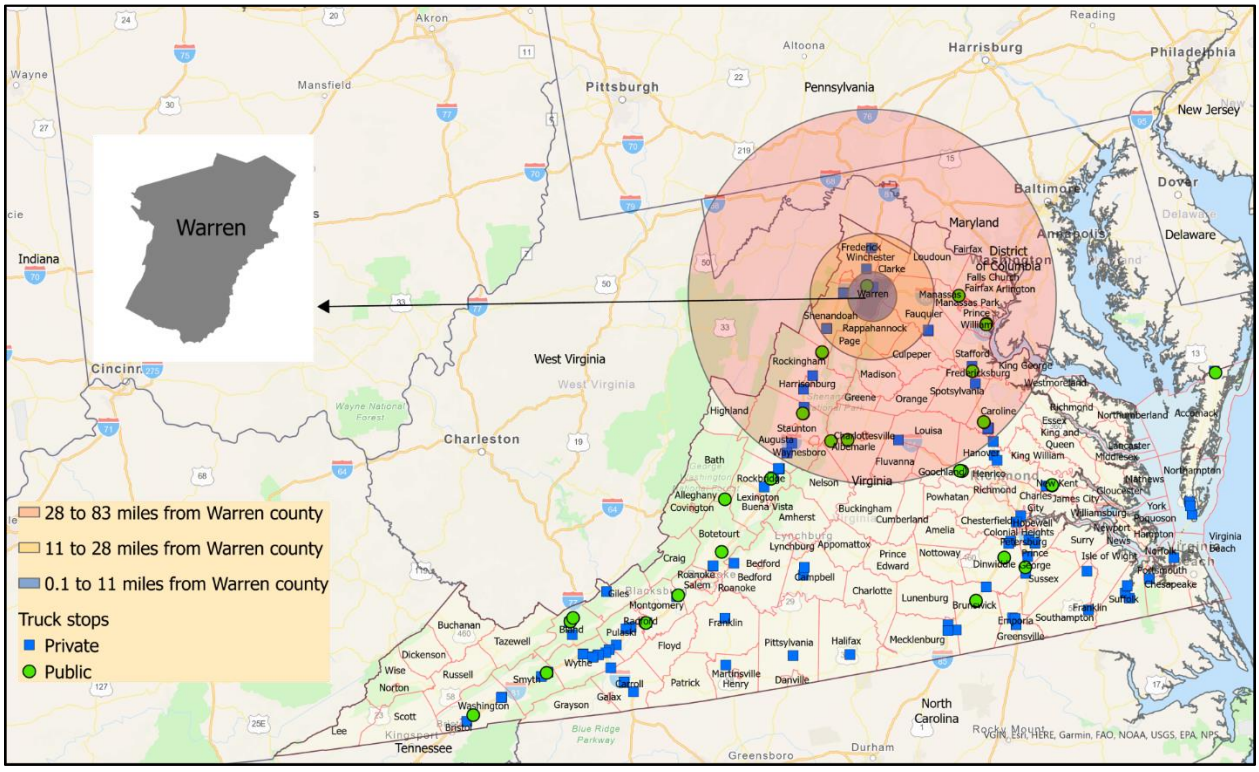

Figure 15. Truck Parking Facilities with Respect to Warren County, Virginia. Stops provided by Johnson (2023). Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri.

Table 6. Forecast Truck Parking Demand (Stops) for Various Distances from Warren County

North American Industry Classification System Code	0.1–11 Miles		11–28 Miles		28–83 Miles		83 Miles+	
	2020	2045	2020	2045	2020	2045	2020	2045
Construction (23)	19	18	18	18	4	5	3	3
Manufacturing (31-33)	38	41	38	40	9	9	5	5
Wholesale trade (42)	18	24	17	23	5	6	3	4
Retail trade (44-45)	156	150	152	146	34	33	20	20
Transportation and Warehousing (48-49)	2,025	2,110	1,971	2,053	428	446	253	263
Accommodation and food services (72)	8	12	7	11	2	3	2	2
Total truck parking space demand	2,264	2,355	2,203	2,290	482	502	286	297
Total demand within Virginia	2,264	2,355	2,203	2,290	386	402	—	—
Change in demand between 2020 and 2045		90		87		16	—	—

— = not applicable.

As appendix B details, the research team estimated this conversion factor to be 4.88 trucks per parking space required. For instance, for the year 2045, within 0.1 to 11.0 miles of Warren County, Table B1 showed an increase in demand of 90 stops, or about 90 / 4.88 = 18 additional parking spaces needed.

Forecast of Offsite Truck Parking Demand Based on Through Traffic

A VDOT-commissioned study by Kittelson and Associates (2022) estimated demand for through traffic along the major corridors in Virginia, using a linear growth rate of 1% for each year for the forecast as veteran freight planner Erik Johnson suggested (personal communication, June 20, 2023). For example, one facility (Longdale Furnace East) showed a 2019 demand of 39. Thus, the forecast demand for 2045—26 years after this baseline 2019 estimate—was estimated as 39 * (1 + 1% [26]) = 49 spaces in 2045. This calculation is repeated for all facilities within 83 miles of Warren County.

Such demand estimates are based on growth at truck rest facilities and do not necessarily reflect demand outside rest facilities, such as staging near a delivery point. These demand estimates also are for spaces, rather than stops, which also explains why the values differ from the values shown in Table 6. In sum, within 11 miles of Warren County, demand forecast will increase from 85 at present to 107 in 2045, or an increase of 22 spaces. An increase of 220 spaces is forecasted for truck facilities located between 11 and 28 miles from Warren County from the present to 2045. For spaces located 28 to 83 miles, an increase in demand of 525 spaces is expected between the present and 2045.

Insights Gained from the Pilot Deliverables

Extent to Which Demand Is Affected by Local Versus Through Traffic

Figure 16 shows how demand attributable to industries in Warren County is forecasted to change between 2020 and 2045 (green). However, because I–81 is a major truck route, through traffic (red) also influences truck facilities in Warren County. For the area in the vicinity of Warren County (e.g., 0.1 to 11 miles away), the estimates of parking demand (as parking spaces) in Figure 16 differ by an order of magnitude.

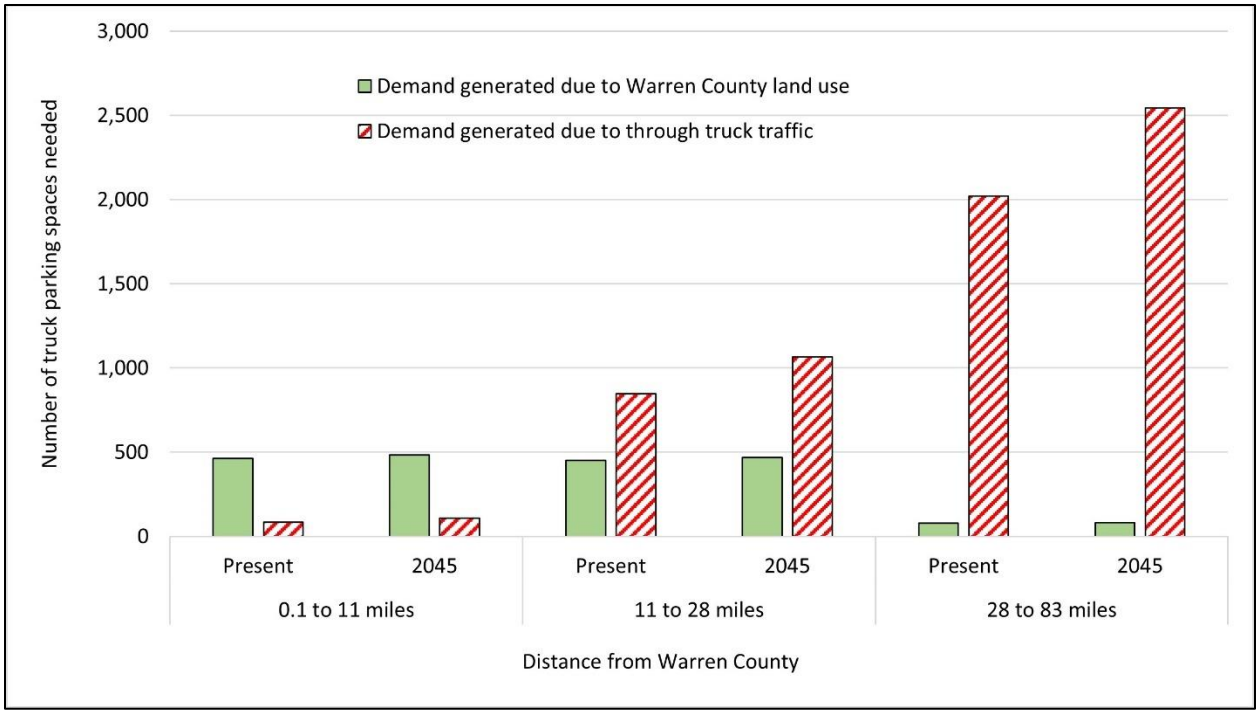

Figure 16. Truck Parking Demand in the Pilot Area, Present, and 2045. Present denotes base year data for 2020 (for land use) and 2019 (for through traffic based on Kittelson and Associates, 2022).

One possible reason why the demand generated by Warren County land use differs from the demand generated by through truck traffic is that the analyst must make judgments about how to apply the FHWA's truck parking estimation tool (Dowell et al., 2022). An example is the research team's conversion factor of 4.88 truck stops per space (see appendix B). Another possible reason is that the two sets of forecasts reflect different phenomena. The estimates from the FHWA estimation tool include stops at multiple locations (Dowell et al., 2022), such as freight unloading, staging prior to delivery, and longer term rest. The estimates from the study conducted by Kittelson and Associates (2022) for VDOT reflect stops at public and private truck facilities only. Although these stops may be used for short-term staging, the numerical estimates do not reflect parking at locations other than truck facilities, such as on the side of a road near a potential business.

A second finding is that for the Warren County area, the growth rates of demand for truck parking differ based on local employment generated in freight-intensive industries in Warren County. The 2045 demand forecast is roughly 4% higher than the 2020 value. By contrast, the increase in demand attributable to through traffic is forecast to increase about 26% during this same period.

Other Observations of Parking Outside of Truck Rest Areas

Several pilot participants noted they had observed trucks parking along the roadside. As suggested by one participant, the research team collected 35 images in Warren, Shenandoah, Frederick, Winchester, Clarke, and Page Counties from Google Maps where trucks parked in undesignated locations such as at road exits. Four of these 35 sites were in a business area (not on the roadway), but 31 were on the side of the road. In practice, therefore, an item to consider is

whether such parking is attributed to the need for staging or attributable to the driver unable to find a suitable place to rest. Possibly, the latter explanation is applicable for 17 of the 31 sites where a truck was parked within 2 miles of an existing rest area (Figure 17), and possibly, the former explanation is plausible for the 14 sites where the driver was more than 2 miles from a rest area (Figure 18). However, because drivers were not interviewed, the precise reason for drivers being parked on the roadside is not known.

Figure 17. Trucks Parked on the Roadside within 2 Miles of a Designated Truck Facility. ©Google Maps. Imagery © 2023 Commonwealth of Virginia, Maxar Technologies, USDA/FPAC/GEO, Map data © 2023.

Figure 18. Trucks Parked on the Roadside More Than Two Miles from a Designated Truck Facility. ©Google Maps. Imagery © 2023, Commonwealth of Virginia, Maxar Technologies, USDA/FPAC/GEO, Map data © 2023.

Possible Short-Term Takeaway from the Pilot Effort

Decisions about the content of the comprehensive local plan rest with the locality, rather than VDOT or the PDC. During the final meeting of the pilot effort, participants suggested having the comprehensive plan encourage freight-intensive areas to identify opportunities for adequate truck parking. The following is one version of this generalized language to incorporate in their comprehensive plans:

> When planning for industrial or commerce parks, developers and landowners should consider the benefit of providing safe and secure parking as a service for drivers engaging with businesses to pick up or deliver goods. Such parking may be located within the industrial area or may be in a satellite location.

As an example of how this type of language could be adapted to a specific county, the researchers consulted the Warren County Comprehensive Plan. Examining the plan showed four chapters in which language such as in the preceding paragraph could potentially be included. Chapter 4 discusses the importance of zoning to achieve key goals such as the provision of diverse housing types, the protection of "environmentally sensitive" areas, and preservation of open space. The county could choose to incorporate language similar to the previously proposed text to achieve a goal of safe and secure parking for drivers making a pickup or delivery. Chapter 6 mentions the use of proffers for industrial development. Chapter 8 points out that the "model [of using voluntary proffers] has also been updated to include industrial/commercial development." Finally, the plan's vision component (shown as a 2018 update) also emphasizes as a high priority "investments in industrial parks to make them more impressive and attractive to businesses" (Warren County, n.d.).

Further discussions with the Warren County representative, who reviewed a slightly different version of the proposed language, showed that more specific language tailored to the county could be used. This language could be placed in reference to chapter 7 (focused on Implementation) and section 4 within that chapter (focused on transportation), in which specific requirements could be developed for the Route 340/522 corridor site plans. That location-specific language provided by Wendling (2023) is:

> Tractor trailer truck parking spaces shall be incorporated into site plans for warehousing and distribution centers in the corridor to allow for periodic rest stops as a service for long haul freight truck drivers. These parking areas should be clearly identified for short-term use from a half-hour to 12-hour time limit. Such parking may be located within the industrial park or at a satellite location set aside for this purpose. Rezonings may also provide an opportunity to request proffers for the areas to be designated as part of the General Development Plan.

Because this language offered by the Warren County representative is specific to the pilot, a limitation is that it may not be applicable to other contexts or communities. One TRP member explained that requiring a private industrial development to provide tractor trailer parking not generated by the development could find resistance within the development community as an undue burden. As an example of an acceptable burden, consider a commercial shopping center. The parking required is directly related to the activity generated within the development. Therefore, a similar application could be considered for industrial base development. Accordingly, the spirit of considering truck parking within zoning may be accomplished through a spectrum of options, and it is recommended that the community engage stakeholders in developing options.

The county representative also pointed out that maps created during the pilot effort were helpful for developing this language because they showed the geographical extent of this need for parking. Figure 19 shows an example of such a map, which was provided at the county's request. The map shows the locations of public and private truck stops and the potential demand for parking.

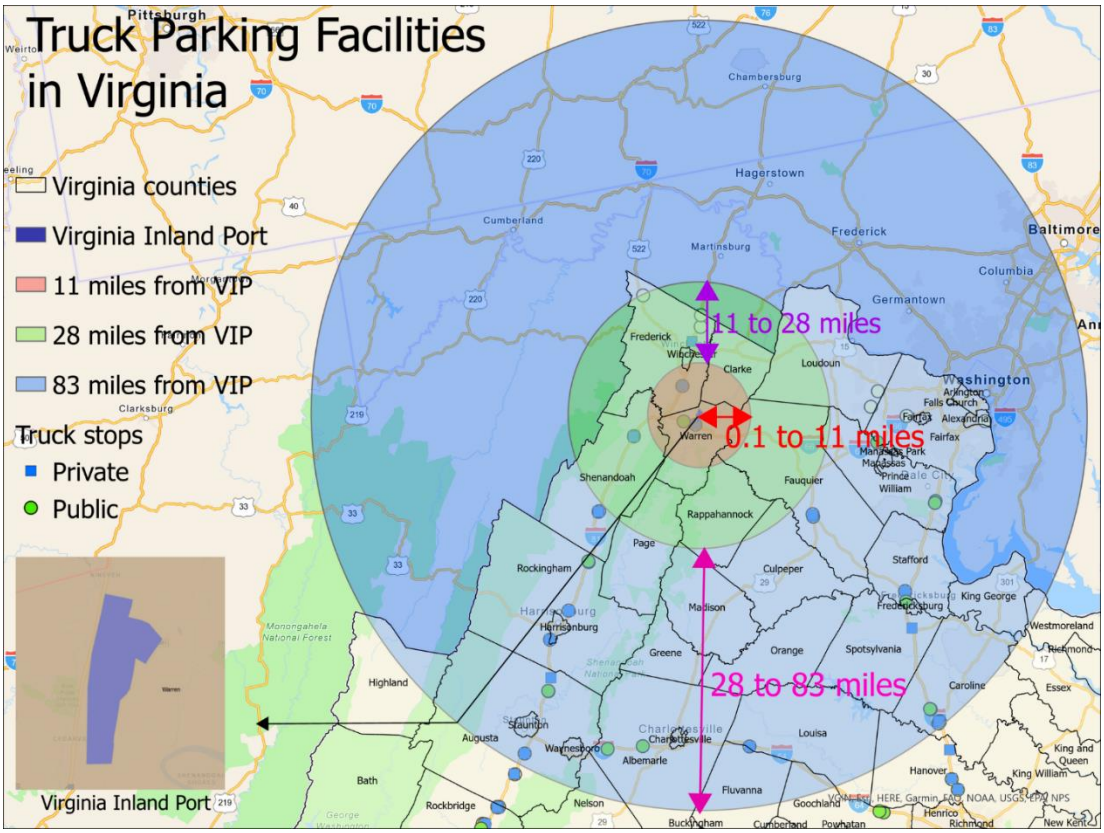

Figure 19. Example of Parking Maps Provided to Warren County. Created with ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used under license. Copyright Esri. VIP = Virginia Inland Port. Note that the distances of 11, 28, and 83 miles from VIP are the three increasing large concentric circles in pink, green, and blue.

Possible Long-Term Takeaway from the Pilot Effort

The final meeting of the pilot suggested a new research topic to participants—with the future arrival of electric trucks, which would logically increase the demand for charging infrastructure at truck rest facilities. Virgina's Electric Vehicle Infrastructure Deployment Plan (VDOT, 2022), which is expected to be updated annually and outlines how Virginia expects to use FHWA-administered funds with respect to the National Electric Vehicle Infrastructure Program, also indicates that demand for truck charging capabilities could increase. The plan refers to a multistate memorandum of understanding signed by Virginia in 2021, indicating that at least 30% of all new trucks sold within Virginia would be electric by 2030.

Summary of Findings from the Pilot

The pandemic does not appear to have materially altered truck patterns within Warren County. For example, of all freight trucks originating in at the Port, 6.9% terminated in Shenandoah County in 2019 compared with 6.2% in 2021. Whether one considers only freight originating at the Virginia Inland Port or freight originating anywhere within Warren County, the geographic distributions based on 2019 and 2021 data are relatively similar.

Within the area that is roughly Warren County (e.g., 0.1 to 11.0 miles of the county's centroid), estimated demand attributed to employment in freight-intensive industries is considerably greater than estimated demand attributed to growth at truck rest facilities. For the former, the research team's application of the FHWA truck parking estimation tool estimated a current demand for 464 spaces, which is considerably larger than the through traffic demand for 85 spaces.

Forecast changes in employment for Warren County are expected to increase demand for truck parking by about 4% between 2020 and 2045. By contrast, through traffic demand is expected to increase about 26% between 2019 and 2045. A search of Google Maps found 31 instances of trucks parked along the roadside, rather than in designated parking areas. However, it is not known why drivers were not parking at truck facilities.

The conclusion of the pilot showed that one way to address a shortfall in parking is to consider truck parking needs during local planning efforts, such as the development of a comprehensive local plan. The specific language may vary by county, and the creation of the language begins with engagement between the community and stakeholders.

Incorporate Feedback from Stakeholders

The three major sets of results—identification of freight planning practices, deployment of a survey, and implementation of a case study—were influenced by TRP comments, interested stakeholders, and case study participants. For example, following a presentation on February 17, 2022, TRP members raised a question about the extent to which commodity value influences the value of freight reliability, thus, the value of reliability was computed for both a mean commodity value and a high value commodity. Table 7 summarizes the insights gleaned as the project progressed.

Table 7. Summary of Insights Gleaned from TRP Members and Case Study Stakeholders

Date	Event	Examples of Key Outcomes
Dec. 1, 2021	Presentation of study proposal at statewide freight advisory committee meeting in Arlington.	• Add as a key practice examination of the business impacts of load-restricted bridges. • As a small case study, look at the history of truck restrictions on Route 15 in Loudoun County and of current truck demand for that route.
Feb. 17, 2022	Virtual presentation of literature review results to TRP.	• Emphasize steps planners should take to include freight in the process. • Find out why overnight statutes prohibiting truck parking at rest areas are not enforced.
March 2022	Email exchange with the TRP regarding the next steps for survey development.	• Organize the survey around the 10 planning factors. • Expand survey to include greater variety of practices. For example, tolling can include variable tolling (for long-distance trips) opposed to tolling for short local trips.
June 7, 2022	Short presentation highlighting the survey at the Annual Planning and Programming Meeting (Richmond District).	• TRP members also encouraged contacts at planning district commissions (PDCs) and VDOT districts to complete the survey. • Email addresses corrected for PDC survey contacts.

Date	Event	Examples of Key Outcomes
November 2, 2022	Discuss summary of survey results (at the Port of Virginia).	• Reach out to the survey respondents and ask if they are interested in implementing any practices. • Virginia is eligible to receive free freight-related technical assistance from the Federal Highway Administration (FHWA).
January 2023–August 2023	Multiple meetings (1 in person, 4 virtual), with case study stakeholders in the Northern Shenandoah Valley Regional Commission.	• Focus on parking concerns in Warren County. • Note that before discussing solutions, the extent of the parking problem should be documented. • Use a combination of existing land-use data and FHWA's truck parking tool.
April 2023	Virtual meeting with FHWA to discuss provision of freight tanks.	• Three courses are available to Virginia stakeholders. It is more productive to focus on only the first two—parking and land use.
September 26, 2023	Meet in Richmond with 3 TRP members representing FHWA, VDOT Transportation Mobility Planning Division, and Virginia Port Authority to discuss Recommendation 1.	• A FHWA-led training course will be available in the spring. Attendees should not be limited to PDCs: Consider localities and VDOT district planners. • Look for opportunities to "socialize" this work so that truck freight gets greater attention in the planning process.

TRP = Technical Review Panel.

CONCLUSIONS

- *Seven categories of truck freight planning practices that could be initiated at the regional level have been identified*. Working alone, the regional planner cannot fully implement the practices but can support them. Some practices are within the locality's purview (e.g., those related to land use) and others remain within a state agency's sphere of control (e.g., incorporating the true hourly value of reliability requires coordination with the state department of transportation).

- *The survey of PDCs suggests that a sizeable percentage of PDCs have high interest in but are not performing certain freight-related planning practices*. These practices include truck parking during emergencies (11 of 22 respondents, or about one-half), examining how shorter truck trips may be an opportunity to introduce electric trucks (8 respondents), incorporating truck parking needs as part of zoning ordinances when sites are developed (7 respondents), and provision of locally funded truck parking areas (5 of 22 respondents, or about one-fourth). Except for the first practice, none of these practices are being performed by any PDCs and may be suitable candidates for a pilot study.

- *The survey of PDCs suggests that a sizeable percentage of PDCs are highly interested in certain freight-related planning practices that other PDCs are already implementing.* Examples are identifying critical gaps in the truck freight network based on lack of resiliency (nine PDCs are highly interested in this practice but do not do it at present, and another five PDCs do this practice), identifying innovative solutions such as truck park-and-ride lots (eight PDCs are highly interested and another six already do this practice), and working with a regional FAC to identify improvements (seven PDCs are highly interested, and another four already do this practice). These practices may be amenable to information sharing among PDCs. Other candidates for information sharing where some PDCs and some VDOT

respondents indicated they do the practice, whereas other PDCs indicated they would be interested in the practice to include innovative truck parking solutions (practice 4), safety analyses for truck freight (practice 6), identify short-term physical improvements from the private sector (practice 9), and load-restricted bridges affecting deliveries for businesses (practice 34).

- *The interests of the PDCs are often heterogeneous.* No practice interested all PDCs. The number of respondents who were either highly interested in or already implementing each practice ranged from one respondent (for two practices involving tolling) to 14 respondents (identify network gaps from lack of resiliency).

- *The process of conducting the pilot suggests that truck freight planning can be encouraged by tailoring techniques to tightly defined regional interests.* Aligning the pilot with the region's technical questions led to a potential solution suggested by the county representative: inclusion of supporting language in the comprehensive plan. Thus, the practices mentioned in the survey are starting points for engagement of regions in truck freight planning efforts with a combination of PDC, local, and VDOT district staff. In this case, the local representative noted that maps provided during the pilot were a key ingredient for this language. Keeping the pilot short (about 8 months) helped ensure a product could be delivered in a timely manner.

RECOMMENDATION

1. *VDOT Transportation Mobility Planning Division (TMPD) should take discrete, actionable steps to encourage planning district commissions (PDCs), in consultation with VDOT district planners, to conduct truck freight planning.*

IMPLEMENTATION AND BENEFITS

The researchers and the Technical Review Panel (listed in the Acknowledgments sections of this report) for the project collaborate to craft a plan to implement the study recommendations and to determine the benefits. This collaboration is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The following information is the implementation plan and the accompanying benefits.

Implementation

Recommendation 1 seeks to elevate truck freight planning within the regional planning process so that specific techniques, such as, but not limited to, those in Table 2 are undertaken. Three action items are associated with this recommendation:

1. *Consider a potential requirement that PDCs must use at least 5% of their SPR funds for freight planning.*

TMPD will consider adding one requirement to the current allocation of SPR funds which are provided by VDOT for PDCs' work program: that at least 5% of those funds be spent on freight planning. For PDCs that may not conduct freight planning at present, this requirement may encourage them to identify freight intensive industries, begin to engage with freight stakeholders including the private sector, and identify key freight concerns. For all PDCs, this requirement may help freight be perceived as a fundamental part of regional planning. For instance, because safety is one of the planning factors, having safe locations for delivery drivers to park would logically be included within the planning process.

This requirement may be complemented with TMPD's strong encouragement that MPOs use at least 5% of their planning funds for freight planning. Because Federal Highway Administration (FHWA) rules govern the use of planning funds, VDOT cannot attach additional requirements to such planning funds. However, such support is provided by several of the planning factors MPOs are required to consider in CFR 450.306(b), such as "increase accessibility and mobility of people and freight."

TMPD's Freight Planning specialist will request that this requirement be considered within 1 year of this report's publication.

2. *Offer truck freight planning training to interested PDCs and VDOT district planners.*

   At an in-person Technical Review Panel meeting on October 2022, when the results of the survey of PDCs were reviewed, two FHWA staff members suggested that VDOT make a proposal under FHWA's EDC-3 Regional Models of Cooperation program. As a result of that proposal, staff from FHWA, VDOT TMPD, and the Office of Intermodal Planning and Investment met virtually on April 19, 2023, to discuss the form that such training would take. Although the initial proposal focused on an FHWA-led initiative to either show how to bring truck parking into zoning or show how to identify emergency truck parking areas, the April 19 discussion showed a more productive approach would be to use a series of 2-hour presentations being designed by FHWA with VDOT participation that would cover the topics of "Truck Parking Solutions" and "Freight and Land Use Strategies" for PDCs and VDOT staff. The development of that training material was placed on hold in September 2023, and FHWA reorganized the Resource Centers that would provide this training. The development of this training material is expected to resume in the spring of 2025. The audience for this training includes VDOT district planners and staff from Virginia PDCs and MPOs. The invitation to this training will also be shared with the Virginia Growth and Opportunity regions that may be able to promote this course to their local freight contacts.

   The FHWA Virginia Division Representative will make this training available during calendar years 2025 and 2026, and Virginia Port Authority's Vice President of Development and Transportation Policy will also promote its availability.

3. *Apply for Implementation funds for one rural PDC to undertake truck-freight planning practices*.

The pilot effort showed that small-scale efforts can be undertaken in less than a year. The pilot required a total of 9 months. One PDC respondent suggested in the survey to have "Have VDOT fund freight-related planning studies through the PDCs," and the survey of PDCs showed interest in freight planning practices throughout the Commonwealth. VTRC Implementation Funds will be requested to support a single PDC to perform truck freight planning. If Implementation funds are granted, then the TMPD Freight Planning Specialist, with support from VTRC, will open a solicitation for rural PDCs (who typically have fewer staff) to apply for these grant funds.

The TMPD Freight Planning Specialist and the VTRC scientist will request these funds during fiscal year 2026.

Benefits

Qualitatively, the benefits of the recommendation, if implemented on a wide scale, are improved efficiency and safety for freight truck transportation in Virginia, where such benefits may pass through to shippers, consumers, and users of the transportation system.

Quantification of the benefits is admittedly challenging but possible. One way to monetize the benefits of this recommendation is to consider the value of deliverables resulting from greater freight emphasis in the planning program. Two practices are considered: practice 46 (implemented in the case study) and practice 9. A rough order of magnitude estimate is that the two practices could yield benefits in the order of $25,000 per occurrence (practice 46) or $20,000 per year (practice 44) as the following subsections discuss and that are based on several assumptions.

Practice 46. Incorporate Truck Parking Needs as Part of Zoning Areas.

For practice 46 to have an effect on the transportation system, two discrete events must occur: a county modifies its comprehensive plan to incorporate truck parking needs and that plan information is used in the actual planning process—that is, at the site plan review—such that a landowner provides truck parking.

That new parking reduces both crash risk and pickup and delivery delays because of a driver searching for a parking location (Kittelson and Associates, 2022). Although both adverse effects have been quantified annually at the national level, driver fatigue plays a role in 10 to 20% of the 4,000 truck crash fatalities and time spent searching for parking adds an extra cost of $4,600 per driver (Ronan, 2019; Sinha and Cohen, 2017), attributing a specific crash reduction or efficiency improvement related to increasing parking spaces is not feasible with the data available. Thus, those are not pursued here. The provision of parking by a private landowner in lieu of the public sector should also not be counted as a benefit as that is simply transferring the cost from one entity to another.

Instead, one potential benefit of practice 46 that can be investigated is that early consideration of parking needs in the land development process reduces the cost of land

acquisition for parking compared with building new parking after much of the surrounding land has been developed. This cost reduction is highly variable and dependent on local conditions.

- FHWA (2012) reported a cost of about $22,000 per truck parking space but noted "The cost per space may not be typical for the nation, particularly given wide variations in land costs among regions and between urban and rural areas." Inflating this number from 2012 to 2023 dollars yields a cost of about $29,000 per space for both land and construction. If land costs were a modest portion of total costs (say 10%), then land costs per truck parking space would be around $3,000.

- Perry et al. (2017) considered a scenario in which two acres were needed to provide enough parking for 14 truck spaces. The study identified vacant land that could support such parking. Land costs varied by location with the highest cost (almost $27,000 per acre for sites in Detroit), which was roughly four times the lowest cost (almost $6,500 per acre for sites in St. Louis). Based on these land cost options, land acquisition adds at most $5,000 per truck parking space after inflation from 2017 to 2023 dollars).

- Data from a media report by Fletcher (2023) suggest a cost of almost $400,000 per truck parking space for a new interstate rest area. If land costs were 10% of total costs, then the land cost per truck parking space would be around $40,000.

Thus, a monetized benefit of successful implementation of practice 46 at one location may be estimated through three steps.

1. Suppose that truck parking is needed at some base year (for staging) and that five spaces are provided. The land acquisition costs for those 5 spaces are 5 × the middle land cost estimate of $5,000 = $25,000.

2. Suppose that land costs double during some period from the base year to a horizon year.

3. Third, compare this outcome with a scenario in which parking had not been provided during the base year but was desired during the horizon year. The new cost would be $50,000. The difference ($50,000 − $25,000 = $25,000) is the monetized benefit of implementing practice 46, which is a one-time benefit if considering the five assumed parking spaces. This monetary benefit focuses only on property values. Although it is possible, early planning may also reduce the cost of other elements of development.

This estimate is, of course, sensitive to assumptions. For instance, Anderson et al. (2009) reported cases of right of way being 10 to 30% of total costs (for transportation projects generally, not rest areas necessarily), which is higher than the 10% figure shown in the previous steps. Regarding the presumed doubling of land prices for some period of time, Hoyt (1968) showed that during several decades, land values in the same region had ranged from a decrease (in some cases) to more than a 10-fold increase in other cases.

Practice 44. Evaluate Freight Projects (Improved Reliability)

Practice 44 entails evaluating freight projects based on the economic benefit of improving reliability. One example of such a project is the short-term operational improvements provided by Florida DOT District 7, which originated from the region's freight advisory committee. One such project improves the turning radius for trucks making left turns. The project sheet (Florida DOT, n.d.) does not give time savings for that project.

However, Yurysta (1974) examined how turning radius can affect truck delays and developed a model showing that an increase in the turning radius from 20 to 50 feet could reduce delays by 6.67 seconds per truck. Consider a situation in which such an improvement affects an intersection that has 200 trucks turning per weekday. Assuming 250 weekdays per year, the value of the savings is (200 trucks per weekday) (250 weekdays per year) (6.67 seconds per truck) (1 hour per 3600 seconds) ($67 per hour from Table 1) equals about $6,200 in travel time savings per year.

Suppose this delay applies to a 25-minute trip for which the free flow time is 20 minutes. If one considers the value of reliability, then the methodology of Table 1 suggests a value of almost $33,000. This reliability value is substantially larger than the travel time value for two reasons: the value of reliability ($160 per hour) exceeds the value of travel time ($67 per hour), and the equations of Guerrero et al. (2019) generally show that when a project reduces travel time, the reduction in the 95th percentile time, and the reduction in the difference between this 95^{th} percentile time and the mean travel time, is larger (see Figure 20). Thus, this particular project could have annualized, monetized benefits of almost $40,000.

Project costs are also highly variable. One improvement project had a cost of $221,000 (Florida DOT, n.d.). Suppose an equivalent annualized cost was about $20,000 per year, which is driven by the discount rate, the life of the project, and maintenance needs. The net monetized benefit of this project would be roughly $20,000 per year.

As is the case with monetizing the benefits of practice 46, this analysis is highly sensitive to assumptions, especially regarding the length of the trip considered (20 minutes), the truck volume, the impact on the 95th percentile time, the type of cargo, and the extent to which the aggregation of these small units of time (e.g., 6.66 seconds per truck) aggregate to useable time.

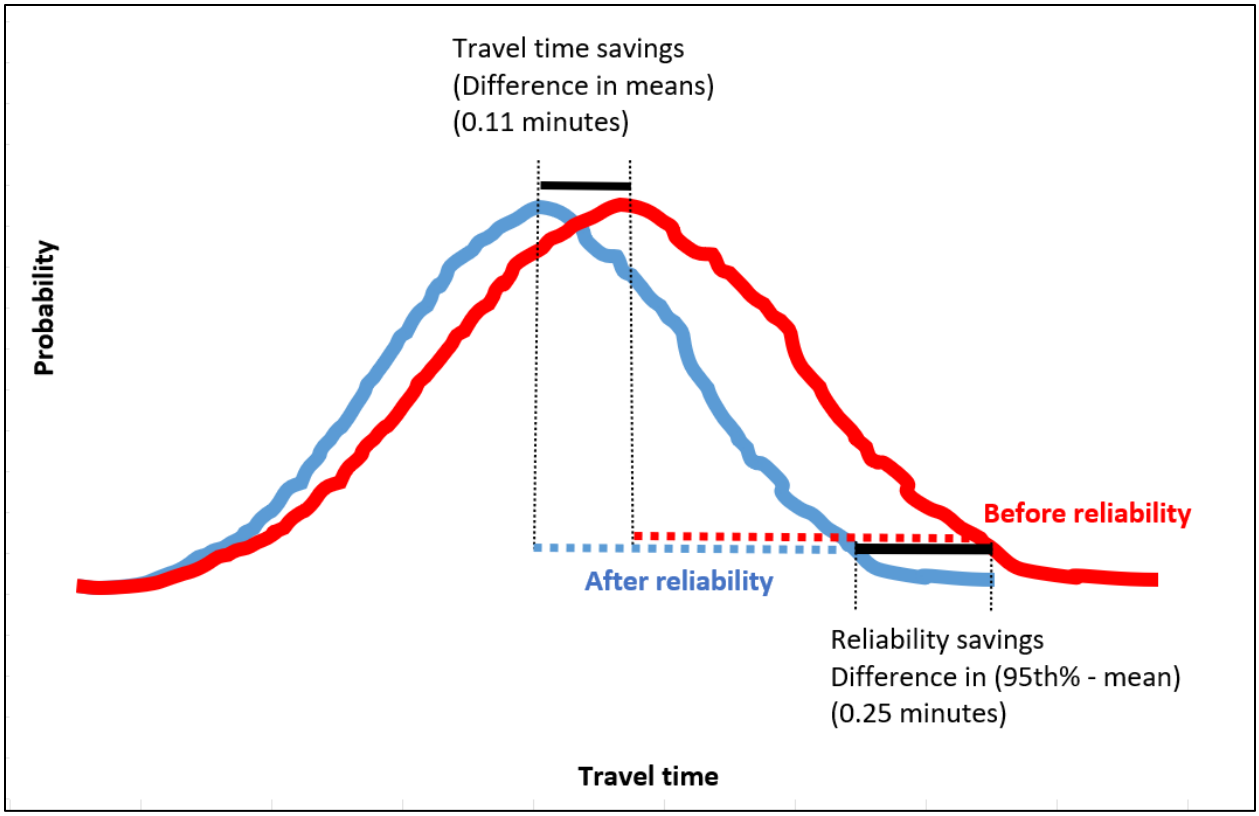

Figure 20. Example of Possible Reliability Benefits for a Single Truck Before and After Increasing the Turning Radius. Solid lines are travel time distributions before (red) and after (blue) the improvement. Upper solid black line is the difference in the means (0.11 minutes). Dashed lines represent reliability before (red) and after (blue). Lower solid black line is the difference in reliability (0.25 minutes). Distributions are rough and exaggerated for effect. Dashed blue and red lines in theory should have the same height but are offset for clarity.

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REFERENCES

Abuzayd, H. Heavy and Medium Duty Commercial Vehicles (Trucks). StreetLight Insight Help Center, October 20, 2020. https://support.streetlightdata.com/hc/en-us. Accessed January 20, 2022.

Anderson, M., Dondapati, C., and Harris, G. *Effectively Using the QRFM to Model Truck Trips in Medium-Sized Urban Communities.* University of Alabama, Huntsville, AL, 2011.

Anderson, S., Molenaar, K., and Schexnayder, C. *Procedures Guide for Right-of-Way Cost Estimation and Cost Management,* NCHRP Report No. 625, Transportation Research Board, Washington, DC, 2009.

Beagan, D., Tempesta, D. and Proussaloglou, K. *Quick Response Freight Methods,* Third Edition. Publication FHWA-HOP-19-057. Federal Highway Administration, U.S. Department of Transportation, 2019. https://ops.fhwa.dot.gov/publications/fhwahop19057/fhwahop19057.pdf. Accessed December 9, 2021.

Boris, C., and Murray, D. *Identifying State Freight Plan Best Practices.* American Trucking Research Institute, Arlington, VA, 2018.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau. *2017 Commodity Flow Survey.* Publication EC17TCF-US. Washington, DC, 2020. https://www.census.gov/content/dam/Census/library/publications/2017/econ/ec17tcf-us.pdf. Accessed June 16, 2021.

Cambridge Systematics, Inc., Prime Focus, LLC, and Heanue, K. *NCHRP Report 594: Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes.* Transportation Research Board, Washington, DC, 2007.

Cattan, C. Email to J.S. Miller. May 27, 2022.

Chicka, R. Duluth-Superior Harbor Planning: A Model for Stakeholder Collaboration, WisDOT Railroads and Harbors Meeting, Duluth, MN, January 30, 2017. https://dsmic.org/wp-content/uploads/2017/02/HTAC-as-a-model-for-stakeholder-collaboration-PowerPoint-Jan-2017.pdf. Accessed December 20, 2021.

Commonwealth of Virginia. *Code of Virginia*. Richmond, 2021. https://law.lis.virginia.gov/vacode/46.2-1224/. Accessed March 11, 2021.

Deke, T. Email to J. S. Miller, May 10, 2021.

Dong, M., Singh, V., Peters, D., Ukegbu, C. C. N., Collars, R., Dack, J., and Duan, L. Towards a Smart Urban Freight Plan. *International Conference on Transportation and Development, Reston, Virginia*, 2019, pp. 347–358.

Dowell, P., Welch, L., Wieghart, B., Guerrero, S., Ward, T., Berndt, M., and Zietlow, B. *Truck Parking Development Handbook*. Publication No. FHWA-HOP-22-027. Washington, DC, 2022.

Dreischerf, A.J., and Buijs, P. How Urban Consolidation Centres Affect Distribution Networks: An Empirical Investigation from the Perspective of Suppliers. *Case Studies on Transport Policy,* Vol. 10, 2022, pp. 518–528.

Duluth-Superior Metropolitan Interstate Council. About the HTAC: Harbor Technical Advisory Committee, Duluth, Minnesota, 2021. https://dsmic.org/about-the-htac/. Accessed December 20, 2021.

Federal Highway Administration (FHWA). *FHWA Freight and Land Use Handbook.* U.S. Department of Transportation, 2012. https://ops.fhwa.dot.gov/publications/fhwahop12006/fhwahop12006.pdf. Accessed December 17, 2021.

———. Freight Planning. FHWA Office of Planning, Environment, and Realty, 2017. https://www.fhwa.dot.gov/planning/freight_planning/. Accessed December 21, 2021.

———. Parking and Staging Requirements in Local Zoning and Planning. U.S. Department of Transportation, 2018. https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/workinggroups/state_reg_lgov_coord/product/requirements.pdf. Accessed January 25, 2022.

———. Forecasts of Vehicle Miles Traveled (VMT): Spring 2020, Office of Highway Policy Information, Washington, DC, 2020. https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf. Accessed April 5, 2023.

Federal Highway Administration (FHWA) and Federal Transit Administration (FTA). The Transportation Planning Process Briefing Book: Key Issues for Transportation Decisionmakers, Officials, and Staff. Washington, DC, 2019. https://www.fhwa.dot.gov/planning/publications/briefing_book/fhwahep18015.pdf. Accessed March 1, 2022.

Fisher, T. Above and Beyond. *Land Line*, July 1, 2016. https://landline.media/above-and-beyond/. Accessed January 25, 2022.

Fletcher, N. Illinois to Add Truck Parking at Three Rest Areas, Transport Topics, Washington, DC, May 10, 2023. https://www.ttnews.com/articles/illinois-parking-spaces. Accessed September 29, 2023.

Florida Department of Transportation (Florida DOT). 2019 Freight Intersection Improvement Projects, Tallahassee, n.d.

Fricker, J. D. and Whitford, R.K. *Fundamentals of Transportation Engineering: A Multimodal Systems Approach.* Pearson Prentice Hall, Upper Saddle River, NJ, 2004.

Gidley, P. Email to E. Quick. June 8, 2021.

Golias, M., Mishra, S., Cherry, C.R., Kohls, A., Murray, D. Giampouranis, D.K., and Liatsos, V. Truck Parking Needs in Tennessee. University of Memphis, Memphis, TN, 2020.

Golias, M., Mishra, S., Pezeshk, S., and Pujats, K. *Improving Resilience of Freight Networks in West Tennessee.* University of Memphis, Memphis, TN, 2018.

Fredericksburg Area Metropolitan Planning Organization. May 2023 FAMPO Draft River Crossing Report, Fredericksburg, VA, 2023. https://fampo.gwregion.org/wp-content/uploads/2023/07/FAMPO-River-Crossing-Presentation-Final-May-2023.pdf. Accessed January 28, 2025.

Guerrero, S.E., Hirschman, I., Bryan J.G.B., Noland, R.B., Hsieh, S., Schrank, D., and Guo, S.B. NCHRP Report 925*: Estimating the Value of Truck Travel Time Reliability.* Transportation Research Board, Washington, DC, 2019.

Gunes, S., Goodchild, A., Greene, C., and Nemani, V. Evaluating Traffic Impacts of Permitting Trucks in Transit-Only Lanes. *Transportation Research Record: Journal of the Transportation Research Board*, 2021. https://urbanfreightlab.com/publications/evaluating-traffic-impacts-of-permitting-trucks-in-transit-only-lanes/. Accessed December 11, 2024.

Guo, J. and Wittwer, E. Best Practices in Freight Planning. National Center for Freight and Infrastructure Research and Education, Madison, WI, 2009. https://midamericafreight.org/wp-content/uploads/2021/07/FR_MVFC03_FR.pdf. Accessed December 11, 2024.

Henrico County. *Zoning Ordinance: Henrico County, Virginia*, 2022. https://henrico.us/pdfs/planning/code-update/Ch24_2022-12-13.pdf. Accessed October 31, 2023.

Holguín-Veras, J., Lawson, C., Wang, C., Jaller, M., González-Calderón, C., Campbell, S., Kalahashti, L., Wojtowicz, J., and Ramirez-Ríos, D. Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips and Service Trips. National Cooperative Freight Research Program, Washington, DC, 2017.

Hoyt, H. Land Values in Shopping Centers. *Traffic Quarterly*, Vol., 22, No. 1, Eno Transportation Foundation, Westport, CT, July 1968, pp. 315–328. https://babel.hathitrust.org/cgi/pt?id=pst.000060089311&seq=393. Accessed September 28, 2023.

Hunter, B. Email to J. S. Miller, January 24, 2022.

Jaller, M., Rivera, D., Harvey, J., Kim, C., and Lea, J. *Spatio-Temporal Analysis of Freight Patterns in Southern California.* University of California, Davis, 2020.

Johnson, E. Email to J.S. Miller and N. Vavitta Parambil, June 8, 2023.

Julien, T. Workshop on the Draft Truck Parking Development Handbook. FHWA Office of Operations, Washington, DC, 2021.

Julien, T. Email to J. S. Miller, January 18, 2023a.

Julien, T. Email to J.S. Miller, August 29, 2023b.

Kam, K. A., Jiang, N., Bujanovic, P., Savage, K. M., Walthall, R., Seedah, D., and Walton, C. M. Finding and Exploring Use of Commodity-Specific Data Sources for Commodity Flow Modeling. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2646, 2017, pp. 77-83. http://dx.doi.org/10.3141/2646-09.

Kim, R. Email to J.S. Miller, June 6, 2022.

Kittelson and Associates, Inc. *Virginia Truck Parking Study, Final Report.* Virginia Department of Transportation, Richmond, VA, April 2022.

Kohler, B. D. Have Excess Parking? Consider Truck Parking Partnerships. National League of Cities, Washington, DC, April 7, 2021. https://www.nlc.org/article/2021/04/07/have-excess-parking-consider-truck-parking-partnerships/. Accessed January 25, 2022.

Koliou, K., Antonoglou, V., and Kaisar, E. Identification of Emergency Truck Parking Location in Florida State with Spatial Analysis Tools. Poster Presentation 22-01943. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, 2022.

Kriger, D., McCumber, M., Clavelle, A., Gan, B., and Chow, T. Freight Transportation Surveys. NCHRP Synthesis 410, Transportation Research Board, Washington, DC, 2011. https://journals.sagepub.com/doi/10.3141/2646-09. Accessed March 3, 2022.

Kuttner, B. Technical Memorandum to the Boston Region Metropolitan Planning Organization: Rest Locations for Long-Distance Truck Drivers in Massachusetts, October 6, 2016. https://www.ctps.org/data/calendar/pdfs/2016/MPO_1006_Truck_Stop_Memo.pdf. Accessed January 26, 2022.

Leach, J. Email to J. S. Miller, June 15, 2022.

Mallett, W., Sedor, J., ICF Consulting, HLB Decision Economics, Lakshmanan, T.R., and Anderson, W. *Freight Transportation Improvements and the Economy.* FHWA, U.S. Department of Transportation, 2004. https://ops.fhwa.dot.gov/freight/documents/improve_econ.pdf. Accessed January 13, 2022.

McDonald, N., and Yuan, Q. Freight Loading Space Provision: Evidence from the US. *Journal of Urban Planning and Development*, Vol. 147, No. 2, 2021. https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29UP.1943-5444.0000688. Accessed January 13, 2021.

McNally, A. and McCoy, K. Freight Planning and Regional Cooperation in the Piedmont Atlantic Megaregion: A Regional Models of Cooperation Peer Exchange Summary

Report. Publication FHWA-HEP-17-101. Federal Highway Administration, U.S. Department of Transportation, 2018.

Mendes, D. Email to J. S. Miller, June 8, 2022.

Miller, J.S. Truck Freight Planning Practices Outside Virginia. On the agenda as "Synthesis of Local and Regional Truck Freight Planning Practices," presented at the Quarterly Coordination and Annual Planning and Programming Meeting, Colonial Heights, VA, 2022.

Multi-Resolution Land Characteristics Consortium. 2019 CONUS Land Cover. Sioux Falls, SD, 2022. https://www.mrlc.gov/viewer/. Accessed July 11, 2022.

Napoli, A. Email to J. S. Miller, March 11, 2021.

Nassif, H., Ozbay, K., Wang, H., Noland, R., Lou, P., Demiroluk, S., Su, D., Na, C., Zhao, J., and Beltran, M. Impact of Freight on Highway Infrastructure in New Jersey. Publication FHWA-NJ-2016-004. Rutgers, The State University of New Jersey, Piscataway, NJ, 2016.

Nordtomme, M. E., Bjerkan, K. Y., and Sund, A. B. Barriers to Urban Freight Policy Implementation: The Case of Urban Consolidation Center in Oslo. *Transport Policy,* Vol. 44, 2015, pp. 179-198. https://doi.org/10.1016/j.tranpol.2015.08.005.

North Central Texas Council of Governments (NCTCOG). *Truck Parking Study: A Freight North Texas Study,* Arlington, TX, 2018. https://resources.nctcog.org/trans/goods/freight/documents/TPSMasterDraftUpdated2018_FINAL.pdf. Accessed May 17, 2021.

Northern Shenandoah Valley Regional Commission (NSVRC). *Northern Shenandoah Valley: 2016-2019 Regional Economic Development Plan*, Front Royal, VA, 2016. http://users.neo.registeredsite.com/5/4/9/18967945/assets/NSV_Region_SET_Plan_November_2016_s9142.pdf. Accessed August 28, 2023.

Perry, E., Oberhart, E., McFerren, R., Marion, S., Adams, T., and Zietlow, B. An Evaluation of Vacant Urban Land for Truck Parking, Mid-America Freight Coalition, Madison, WI, 2017. https://midamericafreight.org/wp-content/uploads/2017/03/MAFC-White-Paper_Truck-Parking-1.pdf. Accessed September 29, 2023.

Pew Research Center. Writing Survey Questions. Washington, DC, 2022. https://www.pewresearch.org/our-methods/u-s-surveys/writing-survey-questions/. Accessed May 10, 2022.

Phelan, T., Mantero, V., Purdy, J., and Kearney T. *National Coalition on Truck Parking: Activity Report, 2015-2016*. Report No. FHWA-HOP-17-026, Federal Highway Administration, Washington, DC, 2017. https://ops.fhwa.dot.gov/publications/fhwahop17026/fhwahop17026.pdf. Accessed September 13, 2023.

Reddy, B. C. Email to N. Vavitta Parambil, May 16, 2023.

Rhodes, S.S., Berndt, M., Bingham, P., Bryan, J., Cherrett, T.J., Plumeau, P. and Weisbrod, R. *Guidebook for Understanding Urban Goods Movement, National Cooperative Freight Research Program Report 14*, Transportation Research Board, Washington, DC, 2012.

Roanoke Valley Transportation Planning Organization. *Vision 2040: Roanoke Valley Transportation: The Constrained Long-Range Multimodal Transportation Plan for the Roanoke Valley Transportation Planning Organization*. Roanoke, VA, 2017.

Ronan, D. Truck Parking Shortage Costs Drivers $4,600 a Year, Expert Says. Transport Topics, Washington, DC, 2019. https://www.ttnews.com/articles/truck-parking-shortage-costs-drivers-4600-year-expert-says. Accessed September 29, 2023.

Schank, J., Hirschman, I., and Elliott, P. Freight Transportation Planning: Best Practices and Benchmarking Survey. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2077, 2008, pp. 9-16. DOI: 10.3141/2077-02.

Sinha, E., and Cohen, M.L. Commercial Motor Vehicle Driver Fatigue, Long-Term Health, and Highway Safety. *TR News*. No. 312, Transportation Research Board, Washington, DC, November-December 2017, pp. 20-24.

Staunton-Augusta-Waynesboro Metropolitan Planning Organization (SAWMPO). 2045 Long Range Transportation Plan, Staunton, VA, 2020. https://sawmpo.org/wp-content/uploads/2023/09/Cover-Page-Contents-Glossary_0.pdf. Accessed December 11, 2024. Accessed May 18, 2021.

Timber Update, LLC. Maximize Your Timber Investment! 2022. https://timberupdate.com/locations/brunswick-county-virginia/. Accessed July 22, 2022.

Township of Upper Macungie. Municipal Code, Upper Macungie, PA, 2021. https://ecode360.com/14517380. Accessed January 26, 2022.

Transportation Planning Research Advisory Committee (TPRAC). Fall Meeting Minutes. October 31, 2021. https://virginia.app.box.com/s/yuj1iaesb3lv556pw7b4cj3p3bbczmz1/file/879592458815. Accessed July 15, 2022.

U.S. Bureau of Labor Statistics. Quarterly Census of Employment and Wages QCEW NAICS-Based Data Files Annual Averages by Area 2020**.** Washington DC, 2021. https://www.bls.gov/cew/downloadable-data-files.htm. Accessed July 6, 2023.

U.S. Census Bureau. OnTheMap. Washington, DC, n.d. https://onthemap.ces.census.gov/. Accessed January 28, 2025.

U.S. Department of Energy. *SMART Mobility: Multi-Modal Freight Capstone Report.* Washington, DC, 2020.

U.S. Department of Transportation. Economic Values Used in Analyses. 2021. https://www.transportation.gov/regulations/economic-values-used-in-analysis. Accessed March 21, 2022.

Virginia Association of Planning District Commissions (Virginia Association of PDCs). Introduction to PDCs. Virginia Beach, VA, 2023. https://www.vapdc.org/introduction-to-pdcs. Accessed September 23, 2023.

Virginia Department of Transportation (VDOT). *Daily Vehicle Miles Traveled (DVMT) by FHWA Vehicle Class 2019: Public Road Segments within the Commonwealth of Virginia*, Richmond, VA, 2020.

http://www.virginiadot.org/info/resources/Traffic_2019/VMTReport_220_2019.pdf. Accessed March 12, 2021.

———. Designated Truck Routes and Length Restrictions, Richmond, VA, 2021. https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=4803162ce73d458a9b8f6d9cb51aa470. Accessed January 14, 2022.

———. Virginia Electric Vehicle Infrastructure Deployment Plan, Richmond, VA, 2022. https://www.fhwa.dot.gov/environment/nevi/ev_deployment_plans/va_nevi_plan.pdf?v=2. Accessed August 29, 2023.

Walton, C.M., Seedah, D.P.K., Choubassi, C., Wu, H., Ehlert, A., Harrison, R., Loftus-Otway, L., Harvey, J., Meyer, J., Calhoun, J., Maloney, L., Cropley, S., and Annett, F. *NCHRP Report 35: Implementing the Freight Transportation Data Architecture: Data Element Dictionary.* Transportation Research Board, Washington, DC, 2015.

Warren County. Warren County Comprehensive Plan. Front Royal, VA, n.d. https://www.warrencountyva.gov/comprehensive-plan. Accessed August 16, 2023.

Wendling, M. Email to J.S. Miller. September 7, 2023.

White, V. Memorandum to Secretarial Officers [and] Modal Administrators. U.S. Department of Transportation, 2016. https://www.transportation.gov/regulations/economic-values-used-in-analysis. Accessed March 21, 2022.

Wilbur Smith Associates and S. R. Kale Consulting. *A Guidebook for Engaging the Private Sector in Freight Transportation Planning.* Publication FHWA-HEP-09-015. FHWA, U.S. Department of Transportation, 2010. https://www.fhwa.dot.gov/planning/freight_planning/guidebook/guidebook.pdf. Accessed Dec. 17, 2021.

Williams, N. and Murray, D. *An Analysis of the Operational Costs of Trucking: 2020 Update*, 2020. https://truckingresearch.org/wp-content/uploads/2020/11/ATRI-Operational-Costs-of-Trucking-2020.pdf. Accessed June 15, 2021.

Winkler, S. Email to J. S. Miller, October 14, 2021.

Woods and Poole Economics, Inc. *Virginia, Maryland, and the District of Columbia, 2018 State Profile, State and County Projections to 2050*. Washington, DC, 2018.

———. *2023 State Profile: District of Columbia, Maryland, and Virginia*. Washington, DC, 2023.

Wygonik, E., Bassok, A., McCormack, E., Goodchild, A., and Carlson, D. Forecasting Tools for Analyzing Urban Land Use Patterns and Truck Movement: Case Study and Discussion of Results. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2547, 2016, pp. 74–82. DOI: 10.3141/2547-11.

Yurysta, T.H. The Effect of Commercial Vehicles on Intersection Capacity and Delay, Joint Highway Research Project No. C-36-17MM, Purdue University, West Lafayette, IN, 1974.

APPENDIX A. SURVEY QUESTIONS ABOUT THE PRACTICES IDENTIFIED BY THIS RESEARCH PROJECT

Table 2 lists the abbreviated title of each practice. The following questions from the survey use the longer practice titles. Each practice begins with a verb, such as conduct, perform, or identify.

1. Does your agency conduct an inventory of industrial land uses for the purposes of preservation through zoning ordinances, redevelopment efforts, or tax credits?
2. Does your agency improve forecasting for truck freight for use in the regional model (e.g., shipper surveys, use of quick response freight methods, or other approaches)?
3. Does your agency quantify the importance of truck freight in the regional economy?
4. Does your agency identify innovative truck parking solutions such as park-and-ride lots?
5. Does your agency identify options for truck parking during emergencies?
6. Does your agency perform safety analyses related to truck freight?
7. Does your agency evaluate technologies such as real-time information for truck parking or truck-shipper matching systems?
8. Does your agency work with a regional freight advisory committee to identify needed operational improvements or other truck needs?
9. Does your agency identify needed short-term physical improvements based on input from the private sector?
10. Does your agency identify needed short-term operational improvements based on input from the private sector?
11. Does your agency identify longer-term needs based on input from the private sector?
12. Does your agency identify restrictions on freight deliveries for individual towns, cities, or counties?
13. Does your agency identify criteria for how future deliveries should be performed?
14. Does your agency use the regional model to examine how different warehouse locations affect VMT and delay?
15. Does your agency examine how a region's increase in shorter truck trips may be an opportunity to introduce electric trucks?
16. Does your agency implement efforts to coordinate land use planning and truck freight planning?
17. Does your agency conduct scenario analyses related to truck freight planning?
18. Does your agency coordinate state and local growth planning related to freight?
19. Does your agency identify critical gaps in the truck freight network based on truck restrictions?
20. Does your agency identify critical gaps in the truck freight network based on missing links?
21. Does your agency identify critical gaps in the truck freight network based on geometric deficiencies?
22. Does your agency identify critical gaps in the truck freight network based on lack of resiliency (e.g., flooding)?
23. Does your agency identify critical gaps in the truck freight network based on limited capacity?
24. Does your agency identify instances of truck trips not using established truck routes?

25. Does your agency determine innovative engineering treatments for trucks (e.g., trucks in transit-only lanes)?
26. Does your agency determine freight flows from public data sources?
27. Does your agency compute freight performance measures?
28. Does your agency identify truck bottleneck locations?
29. Does your agency identify engineering treatments at truck bottleneck locations?
30. Does your agency identify locations where freight traffic is limited in terms of capacity?
31. Does your agency work with private businesses to have a single location for deliveries within a particular urban area?
32. Does your agency investigate freight consolidation centers to reduce urban last mile truck VMT?
33. Does your agency identify any low bridges that affect deliveries to/from businesses?
34. Does your agency identify any load-restricted bridges that affect deliveries to/from businesses?
35. Does your agency identify roadway geometry restrictions, such as narrow lanes, that affect deliveries to/from businesses?
36. Does your agency identify any low bridges that affect deliveries to/from branches of the military?
37. Does your agency identify any load-restricted bridges that affect deliveries to/from branches of the military?
38. Does your agency identify roadway geometry restrictions, such as narrow lanes, that affect deliveries to/from branches of the military?
39. Does your agency conduct truck toll feasibility studies?
40. Does your agency conduct truck variable tolling feasibility studies (e.g., in a day, a long distance carrier may make a single trip and a local carrier may make multiple trips)?
41. Does your agency conduct truck toll pricing studies?
42. Does your agency develop a goods movement action plan?
43. Does your agency evaluate freight projects based on the economic benefit of reducing truck hours of delay?
44. Does your agency evaluate freight projects based on the economic benefit of improving reliability?
45. Does your agency implement ways to consider freight in project prioritization?
46. Does your agency incorporate truck parking needs as part of zoning ordinances when sites are developed?
47. Does your agency investigate the use of county, stadium, or mall lots to provide truck parking?
48. Does your agency investigate the use of designating truck-only parking on certain streets?
49. Does your agency investigate ways to provide locally funded truck parking areas?
50. Does your agency analyze the movement of hazardous materials?

APPENDIX B. SUPPORTING DATA FOR TABLE 6 AND FIGURE 16

The following information describes additional processing the use of the Federal Highway Administration (FHWA) tool requires.

Although Table 5 shows only one value for construction employment, the FHWA tool bases parking demand on three separate North American Industry Classification System (NAICS) categories: 236, 237, and 238. Because construction employment was relatively small, the research team used the average of the parking demand based on each category. For example, for the 1,467 jobs shown in Table 5, the FHWA tool gives estimates of 31, 4, and 19 parking spaces (11 to 28 aerial miles away) for NAICS categories 236, 237, and 238 respectively. Thus, Table 16 shows the average value of 18.

Although Table 5 shows only one value for transportation and warehousing employment, the FHWA tool has one equation for demand based on transportation employment and another equation for demand based on warehousing employment. The research team estimated that 83.8% of this employment is transportation and 16.2% is warehousing based on a review of 2020 employment data from the U.S. Bureau of Labor Statistics (2021). Accordingly, after calculating the demand based on all employees being transportation and all employees being warehousing, these percentages were used to estimate the final parking demand. For example, transportation and warehousing will have an estimated 1,566 total employees in 2045. If all employees worked in transportation, the FHWA tool would estimate parking as 2,393, and if they all worked in warehousing, the tool would estimate parking as 295. The final estimate is calculated as 83.8% (2,393) + 16.2% (295) = 2,053 within 11 to 28 miles, as Table 6 shows.

The study concentrated on the State of Virginia, so the truck parking space is proportionate based on the percentage of major highways. All the major interstates and the percentage of those within Virginia in the 28 to 83-mile buffer were analyzed. Considering I–81, I–66, I–95, and US–15 corridors in Virginia, around 80% of those highways are in the state and the rest are outside. This share is multiplied by the demand to get approximate truck parking spaces needed by the State of Virginia. For example, the total truck parking space demand (for areas 28–83 miles from Warren County) is 482 for 2020, and the demand within Virginia is 482 × 80% = 386. Demand for facilities greater than 83 miles was not calculated as most of these facilities could be outside Virginia.

The duration of stops is not known. Dowell et al. (2022) point out five reasons a truck may stop: long-term rest, federally mandated 30-minute break, emergency, being off duty but unable to park a truck at home, and staging the vehicle prior to pickup or delivery if the truck arrives before a scheduled time. Thus, it is not necessarily the case that the number of stops is equal to the number of parking spaces required.

Accordingly, a procedure was developed as reflected in Table B1 to convert stops to parking spaces. Dowell et al. (2022) suggested that land uses in the “Industrial” category had an average duration of 6.1 hours per truck stop, whereas other land uses, such as transportation, had a lower duration of 3.2 hours (columns 1 and 2 of Table B1). Based on the number of jobs (Woods and Poole, 2023) and the estimates of truck stops (columns 3 and 4), the team estimated

a weighted average duration of 3.69 hours per truck. Under an ideal scenario (e.g., where as soon as one truck leaves another one arrives), a given spot could accommodate 24 / 3.69, or 6.50 trucks, during a 24-hour period. Dowell et al. (2022) suggested that during the peak period, demand for truck parking is twice as high as during off peak periods, such that a rough estimate is 3.25 trucks per space during a 24-hour period. The average of these two scenarios gives roughly 4.88 trucks per space as reported in the last row of Table B1.

Table B1. Conversion of Truck Parking Stops to Truck Parking Spaces

Federal Highway Administration Truck Development Handbook (Dowell et al., 2022)		**Data for Warren County**		
Freight-INTENSIVE Industry (1)	**Average Duration per Stop in Hours (2)**	**Employment Type from Woods and Poole (2023) (3)**	**Number of Truck Stops Needed (4)**	**Duration × Truck Stops (5)**
Commercial	3.2	Construction	1,467	4694.40
Industrial	6.1	Manufacturing	1,177	7179.70
Commercial	3.2	Wholesale trade	250	800.00
Commercial	3.2	Retail trade	2,197	7030.40
Transportation	3.5	Transportation and Warehousing	1,504	5264.00
Commercial	3.2	Accommodation and food services	1,263	4041.60
Weighted average duration of truck stops in Warren County			3.69 hours per truck	
Number of trucks parked in a space during a 24-hour period if trucks arrive in an optimal order			6.50 trucks per day	
Rough estimate of the number of trucks parked in a space when accounting for peak demand			3.25 trucks per day	
Mean trucks served per space			4.88 trucks per day	