Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking

October 2022 | Final Report

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16. Abstract Safety issues due to commercial truck parking shortages are a national concern. National hours-of-service (HOS) regulations limit drivers' time on the road to increase safety by limiting fatigue. This requires drivers to locate safe, secure, and legal parking wherever they are when or before they hit their limits. If drive time is exhausted with no nearby truck parking, drivers may park in unsafe or unauthorized locations to meet HOS requirements, or they may continue to drive while fatigued. As a result, there are intrinsic safety implications to all highway users due to large trucks parking in unsafe locations or truck drivers driving past their allotted hours. With the projected growth of truck traffic, the demand for adequate truck parking will continue to outpace the supply of public and private parking facilities. The current study will help transportation agencies develop solutions to the parking availability problem by identifying effective methods for using data to estimate truck parking demand and areas of parking opportunity, assessing available data sources for estimating truck parking demand and supply, and determining the safest solutions for distributing information on parking availability directly to drivers.		
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Abstract

Safety issues due to commercial truck parking shortages are a national concern. National hours-of-service (HOS) regulations limit drivers' time on the road to increase safety by limiting fatigue. This requires drivers to locate safe, secure, and legal parking wherever they are when or before they hit their limits. If drive time is exhausted with no nearby truck parking, drivers may park in unsafe or unauthorized locations to meet HOS requirements, or they may continue to drive while fatigued. As a result, there are intrinsic safety implications to all highway users due to large trucks parking in unsafe locations or truck drivers driving past their allotted hours. With the projected growth of truck traffic, the demand for adequate truck parking will continue to outpace the supply of public and private parking facilities. This research helps transportation agencies develop solutions to the parking availability problem by identifying effective methods for using data to estimate truck parking demand and areas of parking opportunity, assessing available data sources for estimating truck parking, and determining the safest solutions for distributing information on parking availability directly to drivers.

Acknowledgements

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Introduction

This research focused on ways for state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) to use easily obtainable data to improve safety by understanding truck parking demand and supply opportunities and how truck parking information should be shared with the trucking community. The types of data include truck probe data, land ownership and use data, crash data, and other publicly available geospatial data.

The study results are intended to inform DOTs and other transportation agencies of how to estimate the relationships among truck flows, parking demand, and parking lot availability most effectively and how to disseminate that information to truck drivers in as close to real time as possible.

National, state, and regional studies consistently reveal truck parking shortages and describe them as a significant safety concern. Researchers suspect an inadequate supply of truck parking results in two negative consequences: (1) tired truck drivers may continue to drive because they have difficulty finding a place to park for rest, and (2) truck drivers may choose to park at unsafe locations, such as the shoulder of the road and exit ramps. Finding solutions to the truck parking challenge requires (1) estimating demand, or the total number of trucks that want to park in each location or geographic area, (2) identifying legal, safe, and secure parking opportunities in that same location or geographic area, and (3) disseminating information on parking opportunities to drivers when they need it and in the manner they prefer. Assessing various approaches for accomplishing these three activities is the key focus of this study.

Study Organization

The purpose of this study was to derive insights that will help State DOTs and other transportation agencies mitigate the presumed negative safety impacts of inadequate truck parking. It builds on prior work by the Texas A&M Transportation Institute (TTI) and the Virginia Tech Transportation Institute (VTTI) in mitigating the negative safety impacts of inadequate truck parking. The study involves two main objectives:

- Use big data to understand when and where parking is needed along major corridors and support local and regional planning efforts for better options.
- Push information via technology to truck drivers to enable them to locate available, safe, and legal parking in messaging formats that they will use and heed.

To assess these two objectives, the project was divided into two sets of tasks. The first set focused on estimating parking demand and identifying supply. These tasks included:

1. Knowledge synthesis to understand relevant literature on truck parking and safety.
2. Evaluation of different methods for estimating truck parking demand and determining if the demand information was reliable for understanding parking availability.

3. Assessment of associated approaches for identifying truck parking opportunities (supply).
4. Evaluation of quality issues and biases of different big data sources for use in truck parking analytics.

The second set of tasks focused on getting parking information to drivers. The research team assessed if there was value in the information from supply and demand analysis and other sources and if it made sense to provide this information to the driving community. Further, this set of tasks focused on the best methods to disseminate information.

Methodology and Results

This section provides the methodology and key findings for each of the research areas. It begins with the literature review, followed by the methodologies for estimating demand, identifying supply, and disseminating needed information to truck drivers.

Knowledge Synthesis

The research team reviewed 51 research articles to determine the relationship between truck parking availability and safety, the uses of data to understand parking and safety issues, and truck parking messaging to support safer operations.

A key finding in reviewing relevant literature is the lack of research that specifically ties truck parking shortages to safety problems. The link between lack of parking and crashes is weak, though strong anecdotal information indicates otherwise and truck parking studies seem to make this claim frequently.

Stakeholders often cite lack of parking as leading to safety issues, but an empirical link is missing. This is especially relevant because of high-profile tragedies such as the death of driver Jason Rivenburg and the ensuing Jason's Law [1.□1] passed in his honor, which requires the United States Department of Transportation (USDOT) to focus on truck parking. However, a clear, empirical relationship between lack of parking and safety was not found in the literature.

Instead of demonstrating a clear link, most reviewed studies implied a link to safety problems due to truckers not having safe and adequate truck parking. These problems include jeopardizing the driver's personal safety (as with Jason Rivenburg's death), trucks parking in unofficial or unauthorized parking, running out of hours of service (HOS), and fatigued drivers.

The following sections describe some implied reasons for safety issues related to lack of parking.

Driver Safety

Many truck parking studies reference the tragic death of Jason Rivenburg and the ensuing development of Jason's Law. The Jason's Law Truck Parking Study provided ample information from drivers about safety and issues related to truck parking [1.□1]. While parking is not a typical metric for roadway safety it is an element of safety and security in that drivers feel inadequate parking puts them at greater risk for personal injury or theft.

Issues with Unofficial and Unauthorized Parking

Many studies have focused on presumed or observed safety issues due to trucks parked in unofficial or unauthorized areas. Choosing these areas may or may not be due to parking availability, but it is thought that unofficial or unauthorized parking occurs when drivers cannot find adequate parking otherwise. However, there are some instances where drivers perceive official parking as busy, not a good fit, or inconvenient, even if official parking is available.

In a 2016 truck driver diary study, more than 25% of participants reported parking in an unauthorized location once or twice per week, while more than 36% parked in an unauthorized location three to four times per week [1.□2]. The research also found that trucks were more likely to park in unauthorized locations during evenings and early mornings. Location also influenced the frequency with which truck drivers parked in unauthorized locations, with more than 26% of participants parking in unauthorized locations in urban areas and only 16% parking in unauthorized locations in rural areas, indicating that inadequate truck parking is more severe in urban areas [1.□2].

Many truck parking studies have focused on trucks parking in unofficial or unauthorized areas as likely to cause crashes due to ingress and egress of the trucks on ramps and shoulders and passenger–vehicle interaction. The North Carolina truck parking study identified the number of truck-related crashes on highway ramps within 2 miles of a truck parking facility [1.□3]. During the study period, 13% of truck crashes on ramps occurred within a half mile of a truck parking facility, 22% occurred within 1 mile, and 32% occurred within 2 miles. The study concluded that truck crashes on ramps may be reduced if more truck parking were available and if there were more effective ways to inform truck drivers of nearby available parking [1.□3].

Similarly, another study found that trucks parking on ramps and shoulders were problematic and involved in crashes. In a research study completed by Boggs et al. [1.□4], truck-involved ramp crashes increased by a factor of 2.556 if a truck parking facility was located at the ramp exit, indicating that there was inadequate parking availability nearby and truck drivers were forced to park on the ramps. The researchers also evaluated data on historically observed illegal truck parking events and found that historical locations of illegal truck parking that had a truck stop located at the exit were 1.242 times more likely to have ramp crashes. The results concluded that there are more fatal crashes on interstate entrance ramps and more severe injury crashes on interstate exit ramps, resulting from vehicles attempting to gain speed to enter back onto the interstate. Based on the results, ramp crashes were more likely to occur on diamond-shaped ramps, on ramps with larger shoulders, and during evening hours [1.□4].

While none of the studies provided clear evidence that the lack of parking was the reason for trucks on ramps and shoulders and the resulting crashes, the studies implied that parking was the problem. They also implied that adequate parking might alleviate these issues.

Fatigued Drivers

Several truck parking studies mentioned safety issues related to fatigued drivers. For example, Delaware [1.□5] and Texas [1.□6] truck parking studies considered safety risks associated with fatigued drivers and undesignated truck parking. These studies highlighted issues with roadway safety that might be linked to crashes involving parked trucks in undesignated parking areas and fatigued drivers. In Texas, between 2013 and 2017, there were 2,315 crashes that involved parked trucks, resulting in 138 fatalities. While 70% of the crashes involving parked trucks occurred in urban areas, 55% of the fatalities involving a parked truck occurred in rural areas. The study concluded that speed, lighting, shoulder width, and behavioral factors could all affect crash severity. During that same timeframe, Texas also evaluated crashes involving fatigued truck drivers and found that there were 1,511 crashes where the driver was potentially fatigued. As a result, Texas sought to prioritize truck parking safety needs and identify strategies to improve truck parking safety [1.□6]. In Delaware, more than 27% of crashes involving a truck occurred because the driver was potentially fatigued. The study also analyzed the safety impacts of undesignated truck parking and found that these trucks posed a significant safety risk to their and other drivers [1.□5]. Several states have investigated truck-related crashes in undesignated locations. In general, the records of truck-related crashes were identified by crash or injury severity, district or regional level, corridor, and event characteristics at the time of the crash, such as driver inattention and illegally parked motor vehicles [1.□5, 1.□6].

Additionally, studies show an association between at-fault truck crashes and driver fatigue attributed to distance to truck parking. Bunn et al. [1.□7] found an association between at-fault truck crashes and fatigue, with distance to the next truck parking location and time of day contributing to the impacts. As the distance between the next truck parking location decreased, the number of fatigue-related crashes also decreased; however, as trucks passed a truck parking location, possibly because of no truck parking availability, the number of fatigue-related crashes increased. Fatigue-related truck crashes occurred more frequently if a truck parking location was more than 20 miles away. Fatigue-related truck crashes were also more likely to occur in the evenings [1.□7]. This confirms other studies that showed a connection between fatigue-related truck crashes occurring more frequently in the evenings. The study concluded that fatigue-related truck crashes can be challenging to analyze because drivers may be hesitant to report fatigue for fear of negative repercussions [1.□7]. Despite these records, there is still not a clear link that has been demonstrated between parking shortages and safety issues.

HOS Violations

Many studies mentioned the need for drivers to get required rest due to HOS laws. These laws are in place to help with fatigued drivers. However, like fatigued drivers, drivers who cannot find parking and are out of hours may continue to drive or park in unofficial and unauthorized locations. The Delaware truck parking study reviewed truck drivers' HOS violations between 2017 and 2020 with Federal Motor Carrier Administration (FMCSA) Motor Carrier Management Information System data [1.□5]. The study analyzed HOS violations based on the type of violation (e.g., number of hours over the driving limit) and compared their location data with the first- and last-mile connectors. Driving beyond the 14-hour duty period was the predominant violation, with 116 violations out of 256. Driving beyond the 11-hour driving limit was the next highest violation, with 59 violations. Throughout a 12-week period during the study, hundreds of occurrences of trucks parking in undesignated areas were observed using global positional system (GPS) data, suggesting that analyzing truck parking violation records alone may not accurately evaluate the true number of trucks parking in undesignated locations. The study identified 32 locations with a high frequency of undesignated truck parking. Further analysis of these areas concluded that these trucks were parking in the undesignated areas due to HOS requirements or for staging. The study also found that trucks were more likely to park in undesignated locations for longer periods if the location was near a public rest area [1.□5].

Loss of Parking

Parkways were created to provide drivers with a more scenic route; however, these routes may not be ideal for trucks. The development of parkways may be reducing parking availability and contributing to safety problems, as these parkways are created to add scenic value, not convenience. According to research completed by Bunn et al. [1.□7], parkways have increased deficiencies for truck parking. In particular, the study found that parkways on the designated National Network for trucks did not have adequate truck stops and rest areas, indicating inadequate truck parking along these parkways. The study also identified a positive correlation between the distance to a rest area or weigh station with truck parking capacity and the frequency of at-fault fatigue-related truck crashes [1.□7].

Hesitancy to Use Weigh Stations

Several states have opened truck parking at various facilities, including truck weigh stations. However, a smart parking management study in Florida observed that truck drivers are hesitant to park at weigh stations overnight [1.□8]. The study concluded that improving the utilization of truck parking at weigh stations overnight would alleviate some of the truck parking demand across Florida. The researchers concluded that more research is needed to determine why truck drivers are not willing to use weigh stations for overnight parking [1.□8].

Most of the reviewed literature focused on truck parking as it relates to unauthorized parking, fatigued drivers, HOS violations, and driver behavior. While the literature indicates some relationship to safety problems associated with truck parking, there is not enough research that specifically illustrates the connection or cause and effect between inadequate parking and safety. Instead, the studies implied anecdotally that the safety issues could be resolved or improved if more truck parking were available. Despite the lack of content in the literature review, the anecdotal and implied information provided through academic, public sector, and industrial analysis is strong enough to provide a believable connection. Research such as presented in this study may contribute to resolving some of the problems implied by these previous studies.

Estimating Parking Demand and Identifying Supply

This section identifies ways that truck probe data can support understanding truck parking supply and demand and discusses the data, its reliability, and quality issues to consider.

Estimating Demand

Estimating demand involved evaluating data to 1) determine if there was a way to consistently predict truck parking demand from historical truck probe data; 2) look at data to determine parking supply; and 3) assess data quality issues found in evaluating demand and supply.

To estimate demand, the research team tested three different methods. The data used were a sample of INRIX truck probe data provided by the Maryland Department of Transportation (MDOT) State Highway Administration (SHA). MDOT SHA's data were from the INRIX Trips dataset for March 2019 and May 2019. The study was limited to Howard County, Maryland. Howard County is an area along the I-95 corridor between Baltimore and the District of Columbia and is home to significant freight movements, truck parking, and intermodal facilities.

The three different ways the data were assessed to estimate demand include:

1. Developing a mathematical algorithm to assess clusters of parking.
2. Geohashing the location of points within the data to identify clusters of parking.
3. Testing the reliability of the data in the parking information it provided.

To understand supply and identify opportunities to meet demand, geospatial data from the MDOT SHA were incorporated into ArcGIS. This helped identify potential areas as a solution to truck parking. Finally, this section includes a review of quality issues and biases of the data sources. This is important because it helped to understand some of the key caveats important when using these data. The following sections detail each part of the methodology and results.

Algorithms

The first step to estimate parking demand was to explore the INRIX Trips data to determine what could be used to identify areas of parking activity. After assessing the data elements, the research team determined that stopping trips (i.e., a subset of trips data, including only those that end with a stop) would be the most appropriate form of data to use in an applied algorithm to identify parking. The March 2019 INRIX data consisted of 2,739,674 records, and the May 2019 INRIX data consisted of 2,908,362 records. Additional information highlighting the INRIX data can be found in Appendix A: Method for Estimating Demand.

The research team then developed a method to identify where trucks were parking. The following steps briefly describe this method:

1. Filter and slice stopping trips data (by time or space).
2. Apply artificial intelligence (AI) algorithms to the filtered data.
3. Evaluate results and iterate.

Three AI categorization methods were evaluated using the INRIX data sample to apply AI algorithms. Table 1 highlights the three AI categorization methods used in this task, including the benefits, challenges, and parameters.

Table 1. AI Categorization Methods Analyzed

Algorithm Acronym	Algorithm Full Name	Pros	Cons	Parameters
DBSCAN	Density-based spatial clustering of applications with noise	• Produces best fit to parking cluster, regardless of shape • Good treating noise • Easy estimation • Good with large datasets	• Arbitrarily shaped clusters require more time and power to process and have lower accuracy (false positives and negatives) • Overlapping clusters • Possible "holed" and disconnected clusters • Not well accepted wide range of densities	• Minimum number of samples in a cluster • Cluster point radius
OPTICS	Ordering points to identify the clustering structure	• Applicable to a wide range of cluster density • Good treating noise • Great with large datasets • Offers setting cluster boundaries	• Slow • Hard to estimate parameters • Possibly inconsistent parameters across the whole grid • Difficult to determine cluster boundaries	• Minimum number of samples in a cluster • Cluster point radius or range of values • Cluster boundaries
BIRCH	Balanced iterative reducing and clustering using hierarchies	• Local processing (fast is microscopic clustering analysis) • Best with large datasets • Memory efficient • Good with outliers	• Hard to estimate parameters • Possibly inconsistent parameters across the whole grid	• Branching factor (optional) • Tree threshold (optional)

The research team addressed the optimization of computer resources (processing power in particular). However, the first experiments still required large amounts of time. For instance, the first version of OPTICS (with non-optimal parametrization and arbitrary special partition) for the whole state took over 12 hours. This presented a problem because each of the algorithms needed to be applied several times to find optimal parametrization, compare results, utilize different sets of data, etc. Therefore, the next step in the methodology was to optimize this processing. Three major efforts were performed:

1. Parameters optimization depending on algorithm and data subset characteristics.
2. Spatial and temporal data slicing: The first version of the methodology did not consider time filtering and sliced the data in a square grid. This was not optimal in terms of computer power but also led to outliers produced by points on grid boundaries. The optimal results came when applying each algorithm after filtering spatially by county and temporally by day of the week (Monday through Sunday) and time of day (hours from 0 to 23).
3. Local versus cloud processing: The team migrated the data to Microsoft Azure database storage and the data processing engine to a Microsoft Azure Machine Learning engine. These migrations produced benefits in terms of processing time and made the data and coding available among team members.

The research team also tried to compare the analyzed data with available safety and land use data from MDOT SHA's geospatial catalogue (e.g., additional map layers). The first attempt to create a single map with data organized in layers, including the original stopping trips, clustering results, and safety data, used a web app hosted on Microsoft Azure. Further research would need to be completed to optimize this mapping technique, which was outside of this project's scope.

The algorithm method, while complex, brings great value and reliability to analyzing truck parking. Previous work completed by the research team without using an algorithm to estimate truck parking demand was comparable (i.e., the locations were in the same general area) but not as precise (i.e., the algorithm can more accurately pinpoint exact locations). When evaluating truck parking locations compared to land use data, there is a strong case for a lack of adequate truck parking in locations where freight-specific land use is prominent (i.e., many warehouses and distribution centers).

Geohashing

The size and multi-dimensional nature of truck telematics datasets such as INRIX limit the accessibility and application of the data in truck parking decision-making. These datasets are often too large to be processed and analyzed by traditional methods and tools and require applying specialized tools and access to cloud computing infrastructure. Data transformation and processing methods for reducing the dimension of the vehicle telematics data can enable transportation practitioners to work with these data using more common data tools. Geohashing is a geocoding system that encodes a geographic location into a short string of letters and digits. This provides a data transformation method that can significantly reduce the burden of working with large amounts of geospatial point data, such as truck stopping events, to represent geospatial data in a location-specific context. Each geohash code represents a unique rectangular area. Additional information and images representing this process can be found in Appendix A: Method for Estimating Demand. Each extra character added to the geohashing adds precision to the location it represents.

Geohashes are a quick method for transforming large amounts of point data for simplified proximity and location-based trend analysis. Geohashing can be done using existing packages available in modern programming languages such as R and Python. Maryland's INRIX stop trip dataset from March 2019 contains more than 2.7 million records. The research team applied the following steps for a high-level analysis of heavy-duty truck parking in Howard County, Maryland.

Step 1. Using GIS software (ArcGIS), the data points inside the boundaries of Howard County were identified and extracted.

Step 2. Using the "vehicle weight class" information, the resulting data table from Step 1 was further filtered to extract only heavy-duty vehicles' trips (vehicle weight class = 3).

Step 3. Using coordinates of the start point for each stop trip, a 7-digit geohash was assigned to the stop trip. This information was stored in a new column. The research team also extracted the center point coordinates of all the geohashes with at least one observation assigned to them.

Step 4. The research team then identified and marked the day-of-week and hour-of-day that each event started (Monday to Sunday, hours 0 to 23). This information was stored in new columns.

Step 5. The research team developed a summary table by calculating the total number of stop trips happening in each 7-digit geohash on a specific day-of-week (e.g., Monday in geohash dqcp1mt).

Step 6. The resulting summary table was imported into GIS software and visualized along with geohashed truck crash information and other relevant data.

The research team applied the same methodology to the truck crash data for Howard County. This crash dataset contains data for years 2019, 2020, and a portion of 2021. Per input from TTI's safety experts, crash data for all the available years were combined into one set, and the count of crashes for each geohash was calculated from all the combined 3 years of data. Evaluating truck parking locations with crash data is not as developed or accurate, so more research is needed to better understand how truck crash data can be incorporated into truck parking analysis.

Reliability Testing

The research team also evaluated INRIX data to see if there was reliability from year to year. In other words, were trucks consistently parking in the same locations year after year during the same periods? This evaluation was a critical step in determining if INRIX data could be used to inform decision-makers about consistent truck parking demand that could then be used to inform where truck parking needs to be added.

This task aimed to test the reliability of data provided by INRIX. INRIX data from 2019, 2020, and 2021 were analyzed for the Laurel rest area in Maryland, a high-demand truck parking location in Howard County, Maryland. The core method of testing follows several steps:

1. Choose study site.
2. Geofence research area and define official and unofficial parking area.
3. Extract waypoints of trucks parked at this site during a particular month across 2019, 2020, and 2021.
4. Compare the number of trucks parked in the official and unofficial areas.
5. Compare the ratio of trucks parked in the unofficial areas.
6. Compare the number and percentage of trucks parked in official and unofficial areas based on the parking durations.
7. Check if these numbers are relatively consistent across years.

The results of the reliability testing indicate that the truck parking events are reliably consistent from one year to the next. Table 2 shows the breakdown of authorized and unauthorized parking events and parking durations in 2020 and 2021.

Table 2. Results of Reliability Testing at Laurel Truck Parking Location

Parking Type	Number of Observations (2020)	Percent of Total (2020)	Number of Observations (2021)	Percent of Total (2021)
Total	2,119	-	2,548	-
Location: Authorized	1,344	63%	1,432	56%
Location: Unauthorized	775	37%	1,116	44%
Duration: Less than 1 Hour	1,349	64%	1,549	61%
Duration: 1-3 Hours	431	20%	746	29%
Duration: 3-10 Hours	339	16%	253	9.9%

Additional reliability results can be found in Appendix A: Method for Estimating Demand.

Identifying Parking Opportunities

Following the truck parking demand and clustering analysis, the research team developed a method to analyze available truck parking supply using GIS methods. In this analysis, the focus was again on Howard County, Maryland. Areas were chosen based on the clustering algorithm, the number of truck-related crashes that occurred near the area, and their uniqueness compared to each other. The research team analyzed the following research areas (see Figure 1):

1. Laurel Welcome Center – a well-established, publicly-owned truck parking area.
2. Intersection of MD 32 and I-70 near West Friendship – a more rural area than the others.
3. Waterloo and Jessup Area – a major industrial/commercial area.
4. Intersection of MD 100 and US 29 near Autumn Hill – privately owned land near a shopping/residential area.

Data layers were sourced from publicly available databases, including Maryland's GIS database and the Chesapeake Conservancy. If the layers were in polygon form, they were changed into raster layers. A raster layer is a matrix of cells arranged in columns and rows, where each cell includes information to produce an image. Then, all raster data were reclassified to turn qualitative data of the layers into quantitative values, based on the level of interest in those qualitative properties. Additional images highlighting these data layers can be found in Appendix B: Method for Estimating Supply. Using a scale of 1 to 5, each layer was reclassified on different criteria by low to high suitability, respectively:

- Land Ownership – Exempt, Industrial, and Commercial were given values of 5, while parcels such as residential or agricultural layers were given lower values.
- Land Use/Land Cover – values were assigned depending on type of land. Water and wetlands were given a value of 1, Industrial and Commercial were valued at 5, Bare ground and Forested areas were valued at 3.

- High-Res Land Cover – like land use/land cover, areas were classified from high to low: impervious surfaces, grassland, brush, forested, buildings and quarries, wetlands, and bodies of water.
- Terrain Ruggedness – low (flatter land) through high (more hilly land) ruggedness values were reclassified as 5 through 1, respectively.

Using the Suitability tool, layers reclassified in the previous step were combined and each assigned a weight based on how a real-world analysis might consider these layers against one another:

- Land Ownership: 40%
- Land Use/Land Cover: 20%
- High-Res Land Cover: 20%
- Terrain Ruggedness: 20%

In the result of this tool, a new layer was created that shows the suitability of a given area in Howard County. The Zonal Statistics tool was then used to find the average suitability value over each parcel in the Land Ownership layer to provide the average suitability value over each of these parcels. These values were then spatially joined with the relevant parcel in the Land Ownership layer to take the values from the previously created raster layer and relate them to the layer over which they were averaged. This then allows the Land Ownership layer to be filtered by suitability value. In this analysis, all values below 3 were filtered out, as anything at this value will likely not be of interest. Figure 1 shows the most suitable locations to add new truck parking facilities based on the analysis.

Using the Generate Drive Time Trade Areas tool, parcels can then be filtered by proximity to the clustering area determined from the previous task, which helps further filter the Land Ownership parcels to a list that is much more manageable to filter for the following steps manually. Using Sort by Location, parcels can be filtered by the different time areas, beginning with the shortest time of 5 minutes. Depending on availability of parking in this area, the time may need to be expanded to 10 minutes, and then 15 minutes, as necessary. There are 97,271 total land ownership parcels within Howard County. After the analysis was complete, only 5,924 remained.

Future work to develop this methodology could use other pertinent map layers not suitable for reclassification and suitability analysis to help further determine viable land parcels to consider. Potential considerations would include:

- Aerial photography
- Nearby receptors
    - Human (residential, etc.)
    - Environmental/agricultural
- Road/pavement characteristics (e.g., can the parking lot pavement handle trucks, pavement strength, etc.)
- Access to facilities
    - Power

- Water
- Trash collection
- Security

- Environmental equity (e.g., avoid adversely affecting disenfranchised areas and people)

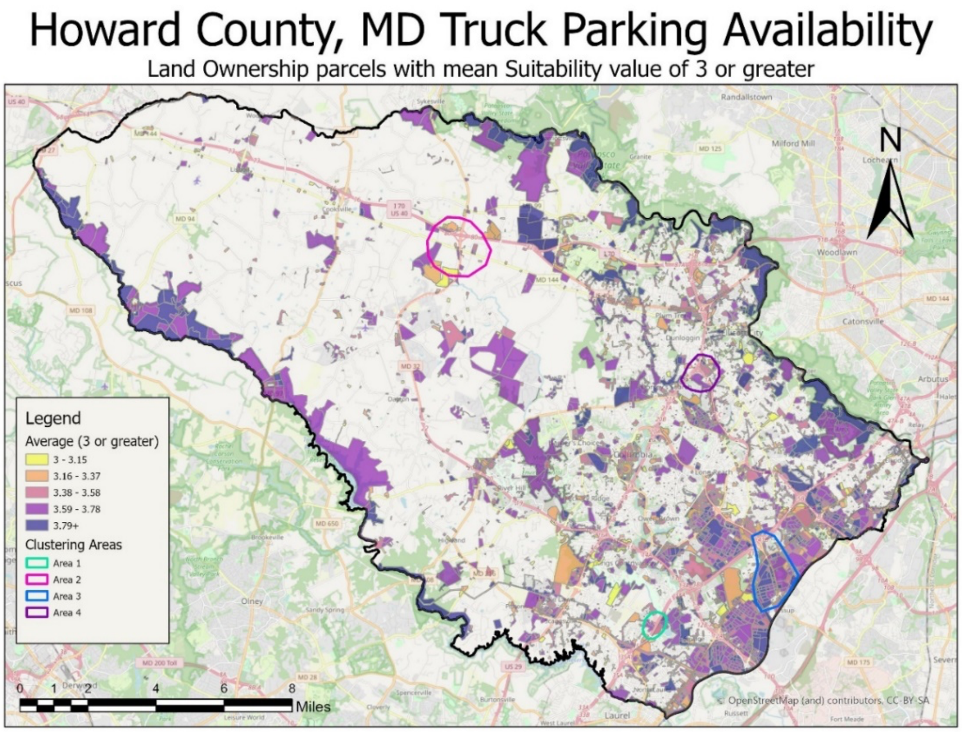

Figure 1. Map. Final map of truck parking availability analysis.

This process helps GIS tools reduce the list of possible parcels quickly and objectively to a more manageable list. While this automates a large portion, ultimately, any viable parcels should be visually checked for usability, such as using Google Street View or in-person observations. If the considered parcel is privately owned (i.e., Industrial and Commercial parcels), owners should be contacted for use of their property for truck parking opportunities.

Quality Issues and Biases of Big Data Sources

There are several methods that have been used to assess truck parking needs, but each has its own limitations, such as coverage limitations, inconsistency, and errors. The methods to analyze truck parking often entail cumbersome data that require expertise in data analytics. Some of the big data sources used in truck parking research are GPS data from commercial vendors such as INRIX and American Transportation Research Institute (ATRI) and available geospatial information like land use or property shapefiles. However, these data have several limitations important to consider when assessing their quality and biases. For example, the data are a sample of the population, they can be cumbersome to analyze and require big data analytics, they may have an over-representation of a type of truck, and they may be inconsistently available.

The following section describes some of the key issues and biases to be aware of in using big data. It provides information on coverage and assessment as well as other sources of information.

Coverage

Not all trucks are included in the database, and regardless of probe data source (INRIX, ATRI, HERE, etc.), there is a range of coverage. For this study, the data represent approximately 15% to 20% of total truck movement in the region. This is based on correspondence with INRIX and previous truck parking studies for MDOT SHA [1.□9]. Second, an expansion factor is needed to understand the population and to interpret the full impact.

As they relate to safety, data on truck parking citations and crashes are often missing data points or have reporting errors, and the data are not transferrable to another state. There are data biases in terms of availability of data in urban and rural communities, too. There is little to no data available in rural areas. Hence, most of the analysis takes place for the urban areas [1.□4, 1.□10].

Despite the limitations, in lieu of daily manual counts, probe data are a strong source of information.

Bias and Characteristics

Data from commercial vendors are not always transparent in terms of what is in the dataset, and there is a range of information among providers to describe the trucks. This lack of transparency and different data methodologies among vendors can lead to inconsistency across data sources, which can add to the limitations of truck parking analysis. Probe data do not provide vehicle classification (only three vehicle types), and they lack information on the type of operation (long-haul versus local). The data lack information on vehicle characteristics that may reveal more about truck parking behavior (type of cabin, single unit vs. combination/tractor-trailer). They have low temporal resolution of waypoint data (every few minutes). There is a constant change in vehicle identification numbers, which sometimes provides an error for any stopping/parking event that crosses midnight and reduces the accuracy of the metrics needed to describe the parking behavior.

Cumbersome Analytics

Processing big data can often be cumbersome. In this research project, INRIX data were analyzed using algorithms and geohash methods, and depending on data size and complexity, processing can be difficult. It is important to consider the data characteristics and best analytical options to reduce complexity. For example, in this study the geohash method represents aggregate behavior for a location. If a large geohash is used, it can mask the local variability of the data. Hence, it is best to calculate the smallest geohash possible, and then metrics for larger geohashes can be built from that. The algorithm method is a cumbersome and time-consuming process that requires extensive knowledge in data processing. However, once it is set up, it can process the data and provide easier assessment of big data sources.

Because of data size and complexity, researchers will often use machine learning techniques (geohashing and algorithms) and rely on GPS expansion factors to determine where trucks are parking among other truck parking characteristics. However, these forms of data analysis also come with limitations.

Machine learning can be used to analyze truck parking data. For example, Mahmud et al. [1.□11] used a bi-level unsupervised machine learning approach along with K-means clustering (an algorithm that identifies natural groups or clusters in ungrouped data) to identify truck parking clusters based on the amenities offered at a truck parking facility. This approach is valuable because the unsupervised machine learning method can handle complex variable correlations and noise in the dataset. However, this approach has limitations. First, the K-means clustering approach only allows one facility type (full service, partial service, no service, etc.) to belong to one cluster type. This means that the clusters are only representative of the majority presence of the facility type in the area. Second, there is still a need for a local understanding of the area to truly understand truck parking needs and issues [1.□11]. While data analysis can provide some insights, it is not a substitute for on-the-ground knowledge.

Another approach to analyze truck parking is to use GPS expansion factors. For example, Corro et al. [1.□12] used the Roadway Volume Expansion Factor (RVEF) method, which uses data from Weigh-In-Motion (WIM) stations to estimate the number of trucks that will use a rest area on a given day in Arkansas. However, the RVEF method does not consider the fact that not all truck drivers use WIM stations, and it is also biased toward pass-through trucks. Based on the data available in this study, it was not possible to evaluate the expansion factors over time and space. In other words, the results do not indicate if the expansion factors are reliable from season to season or outside of Arkansas [1.□12]. While one data analysis approach may work well in one location, it may not work well in another because the necessary data may not be available.

While these methods can make it easier to assess big data, they often require extensive time and expertise in data processing and analytical methods. Regardless of the analytical approach, the results are still dependent on the type, quantity, and quality of data available. To fully understand truck parking needs, accurate and reliable data must be present.

Parking Detection Errors

Big data may not always be from probe sources and may come from cameras and sensors or other detectors. Even these have challenges important to consider in parking analysis. For example, truck parking space detection systems are one of the preferred methods to receive real-time parking information for truck drivers. Based on the results from Morris et al. [1.□13], there are several quality issues related to these systems. Due to lighting and visibility, it is more likely that detection errors will occur during nighttime hours compared to daytime hours. Driving and parking behaviors (e.g., drivers not parking correctly in spaces) can also cause detection errors. The researchers determined that these truck parking space detection systems would benefit from increased broadband speeds, which could improve reliability and reduce the need to house data onsite [1.□13].

Similar studies have also found issues with parking space detection errors. Based on a parking detection technology evaluation study completed by Sun et al. [1.□14], three of the sensors evaluated performed well, with a 95% accuracy rate to indicate vehicle turnover and occupancy. The study also found that if smaller vehicles, such as passenger vehicles or motorcycles, park in the spaces, then more sensors should be implemented, as smaller vehicles can miss the sensors and not accurately report that a vehicle is parked in the location. One of the challenges with the sensors found in this study is that at times the sensor status would fluctuate between on and off even when a vehicle was parked in the space. Another challenge with the sensors, based on the study results, was that rain could affect the functionality of the sensors [1.□14].

While truck parking space detection systems add value and are critical in providing accurate and reliable space counts for dissemination to truck drivers, there are several limitations that can result in detection errors. Transportation planners will need to remain vigilant regarding these devices and make sure they are well maintained. Without proper care and maintenance, the reliability of these systems will suffer, and drivers will not receive the accurate information they need.

Inconsistent Reporting

One challenge with evaluating truck parking safety is the inconsistent reporting from state to state. Parking citations and crash data are not uniformly reported across the country, and more fine-grained analysis is needed to determine patterns. Survey respondents may not be honest about parking illegally or feeling drowsy or tired, so the number of unauthorized parking and fatigue-related crashes may be underreported [1.□4, 1.□10]. Inconsistent reporting can create challenges when trying to analyze truck parking safety, especially at a national level.

Observational Data

Ground-level observations, such as manual truck parking counts where transportation practitioners go into the field to observe the number of trucks parking at a location, are another common data source for truck parking studies. Often, data are collected using ground-level observations, including site surveys and video recording. There are limitations on the amount of data that can be obtained due to high costs and lack of human workforce. The reporting for such data is subjective and requires detailed guidance [1.□8, 1.□15]. While time consuming and costly, ground-level observations are still important for establishing the ground truth for actual truck parking needs. Even with great sources of data available, transportation planners should still collect this information as it can help explain truck parking needs accurately and determine if the other data sources, such as probe data, are consistently reliable.

Smartphone and web application data are often used in truck parking studies, including Trucker Path, Park My Truck, Trucker’s Friend, FindFuelStops.com, etc. Often, these data are collected by crowdsourcing responses from truck drivers using the application, which can be subjective. Based on an interview with Trucker Path and the results of several truck parking studies, users are unable to provide data about truck parking at undesignated locations, and the demand is only provided in three levels: full, some spaces, and a lot of spaces. The registered truck facilities are geofenced and users cannot enter information onto the app unless they are within a certain distance from the truck parking facilities [1.16, 1.17, 1.18]. Crowdsourced information can be very beneficial, but there needs to be a way to verify that the information is accurate; otherwise, it will not be useful.

When considering truck parking demand and new opportunities for truck parking, it is important to fully understand the data characteristics. Quality issues and biases are present across datasets, and there is a range of coverage, representation, and transparency. Data processing can also be a cumbersome process, which requires staff familiar with using algorithms and geohash methods.

Packaging Information

The research team decided that an important product of this section was to develop an interactive map of the data. The team created an ArcGIS online map with all the data layers so that readers of this study and future researchers can explore the data in detail and replicate the analysis. The link for this map is: https://arcg.is/0rHnGH, and an example is in Appendix D: ArcGIS Static Images.

Getting Information to Truck Drivers

This section includes the methods and results of reviewing the information in the previous section with trucking stakeholders such as drivers, logistics managers, highway and transportation officials, fleet services, and technology companies. The purpose was to gather feedback on parking information dissemination to determine the benefit to drivers and the best delivery method to the driving community.

In reviewing the literature, the research team found that truck parking information systems and in-cab devices are important for getting information to drivers. For example, in Tennessee, truck parking availability is determined using the SmartPark system, which detects a vehicle entering the parking area by one of the ingress detectors. In the *SmartPark Technology Demonstration Project*, it was observed that dynamic message signs were overwhelmingly the most effective means of disseminating traveler information despite availability of online and mobile apps [1.19, 1.20]. While messaging signs may be the most common and effective method for disseminating truck parking information, they are not always effective [1.13].

Smartphone applications, such as Trucker Path, and web-based platforms, such as 511 programs, are becoming more common, but they are not always accessible to truck drivers, especially in rural areas with little to no access to the internet. In-cab GPS systems are another option for disseminating truck parking information, but they are not always accurate [1.13].

While all messaging strategies may have limitations and may not work for every driver, they are still vital tactics to get the needed information about truck parking to the drivers. It is important for transportation planners and other stakeholders to remember that each person receives and understands information in their own way, so relying on one type of messaging may result in some drivers not receiving the necessary information. While there are several ways data can be used to assess truck parking demand and evaluate new opportunities for truck parking, it will remain critical to obtain information from truck drivers, transportation planners, and other stakeholders so that the information is accurate and the right information is relayed to those who need it.

Stakeholder Interviews

Throughout March and April 2022, the research team completed 20 stakeholder interviews to obtain feedback on truck parking information and to determine the best, safest, and most effective information dissemination technologies and desired content of information messaging. The stakeholders interviewed included State DOT staff, technology company representatives, shipping companies, and truck drivers. The 1-hour interviews were conducted using Microsoft Teams and were recorded after participants provided consent.

Key Findings from Stakeholder Interviews

The stakeholder interviews provided important perspectives on current practices and lessons learned with regard to collecting, analyzing, communicating, and using truck parking information. The purpose of the stakeholder interviews was to determine the best way to get information about truck parking availability to drivers and the preferred message content. More detailed information about the findings from the stakeholder interviews can be found in Appendix C: Key Findings from Stakeholder Interviews.

Feedback on Demand and Supply Information

The stakeholder interviews verified the presumed usefulness of providing parking availability data and for having data on parking opportunities.

In terms of having data on parking availability, stakeholders supported traffic, volume, and parking concentration information that could help truckers understand routing and parking options and potential availability. This type of information is valuable if it provides drivers with better information than general observational data, which is what most stakeholders currently have.

Data on parking location opportunities mostly pertained to the State DOT stakeholders who could make decisions about where to open parking capacity or operate the system to support awareness of parking options. They reported that it is important to filter opportunities for parking that the public sector can control, buy, or sell, and that it is important to screen property carefully for opportunities before moving forward in any planning process. Additionally, it is necessary to consider corridors, fuel, amenity locations and/or density, and feasibility factors rather than only relying on land area, such as locations not next to residential or incompatible uses, paved locations, and other aspects that would make it conducive to parking. Further, the State DOT representatives cited pushback considerations from communities who perceive truck parking negatively.

The lessons gleaned from the interviewees on truck parking information, however, are that accurate, reliable information can support the trucking community. Getting parking information out to drivers is an important element of solving the truck parking problem.

Feedback on the Best Ways to Disseminate Information

The following are the key points that stakeholders presented related to disseminating information.

Preferred Applications

The Trucker Path mobile app is currently the preferred means by which truck drivers locate information about truck parking availability. The app has 1 million active users each month, comprised of approximately 30% of the long-haul market. The truck parking information is driven by crowdsourced information from other truck drivers and can predict the likelihood of a driver finding parking at a given location at a given time.

Interviewees expressed the desire to have truck parking information in one app that can be used in every state, as opposed to having an app for specific states or areas only. It may not make sense for State DOTs to create truck parking availability apps or websites, as truck drivers may be unwilling or less likely to use them. A national-level app would be more useful to truck drivers.

With grant funding support, government agencies should deploy detection technologies and predictive algorithms to reliably estimate how much parking will be available by the time a driver arrives at a public truck parking location. Interviewees offered that State DOTs should focus their efforts on detection technology and disseminating truck parking information for public facilities through API, installing dynamic signs or communicating information about parking availability at private facilities. Private truck stops are often unwilling to indicate if their truck parking spaces are full out of concern that truckers will not make fuel, food, and other purchases at their truck stops if they know that parking is not available; as a result, collecting truck parking availability information from them will continue to be challenging.

Electronic Logging Device (ELD) Sources

According to the stakeholder interviews, disseminating truck parking information on ELDs would be helpful, but different truckers use different ELDs and different ELD software. Therefore, a limitation with providing truck parking information via ELDs is that the messaging will not reach all drivers. The interviews found that sharing information via ELDs would be most helpful if they could provide information on upcoming truck stops, how many spaces are available at those locations, and traffic updates. Several truck drivers expressed interest in having truck parking information transmitted through their ELDs.

Current Information Technology System Solutions

Several states use a different way to show truck parking information on highways using roadway signage. Due to the differing technology preferences and number of parking spots available per site, each agency determines what the threshold for "low" will be at each of its sites.

Truck drivers interviewed for this project provided that dynamic truck parking information signs are helpful when they show availability within a close distance—5 miles or nearer. Further than that, the information is not useful because by the time they arrive, the parking may not be available.

Regulations prohibit drivers from using hand-held devices while en route, so third-party vendors and commercial fleets will be tasked with finding a way to integrate truck parking information management systems data with the hands-free technologies currently used for fuel efficiency, supply chain management, and driver logging.

Feedback on the Desired Content of Messaging on Parking

The following provides feedback on desired messaging about parking availability for the trucking community.

Parking Availability

The truck drivers who were interviewed for this project preferred that mobile apps, signs, and other messaging technologies communicate how much parking is available at exits/rest areas that are relatively nearby (within 5 miles). If a sign provides the number of spaces that are 25, 50, or 100 miles down the road, trucks ahead might take up all the available spaces by the time the driver arrives. Several truck drivers expressed frustration at dynamic message signage that did not show the actual number of spaces, as they felt this signage was less reliable.

In-Cab is Best

Through the stakeholder interviews, the research team found that simple and minimal information works best. ELDs and other in-cab devices should display minimal information (e.g., “Truck parking/rest area/weigh station 2 miles away” providing the number of spots available there) as a pop-up to avoid confusing and distracting the driver. The interviewees also recommended there be an option to pull over and open a mobile app for more information on facilities and amenities.

Accuracy is Key

The prevailing theme reiterated throughout the stakeholder interviews was that messaging platforms, whether in-cab or outside the cab, need to display correct, reliable information in real time. Accuracy and reliability are important when disseminating information to drivers. Drivers need reliable information in real time about parking, facilities, and amenities to make effective use of their time and resources, which is crucial to the supply chain and the economy.

Discussion

This research developed a method to estimate truck parking demand and supply opportunities, measure reliability of truck parking data, and understand trucking community information dissemination preferences using a case study of Howard County, Maryland. The findings contribute to strategies and insight for state and local transportation planners who are focused on addressing inadequate truck parking in their areas.

For estimating demand, big data analytical approaches can help identify precise locations of truck parking occurrences. These processes help demonstrate ways a DOT can process probe data to identify clusters easily if computer processing skillsets are available. Further, the reliability testing confirmed that the method of analyzing INRIX data can yield reliable information over time about parking availability, as there is consistency in the data year over year.

Based on the analysis of truck parking demand, there are strong options to process geospatial data in relation to demand data to identify opportunities to expand or add parking capacity. Geospatial information can be layered and weighted to identify key areas suitable to support parking demand. One area of bias is the method for weighting the suitability, which may be subjective. Further research is needed to evaluate ways to streamline and automate this process, allow for changes to the weighting procedure, and bring in more data sources.

Further, there is value in transportation agencies providing information, perhaps from a centralized source, that is easy to use for truck drivers to obtain or that is standardized for multiple resources (in-cab, signs, 511, etc.).

Conclusions and Recommendations

This work demonstrates a concept for how State DOTs and transportation planners can analyze truck parking demand and identify truck parking opportunities in their local areas, assuming they have access to data that would allow them to replicate the information presented in this study.

The process for evaluating truck parking demand produced a precise analysis of where trucks are parking, which is important for transportation decision-makers as they attempt to address inadequate truck parking. State DOTs and other transportation decision-makers can also use geospatial layers to enhance the demand analysis and understand supply opportunities. There seems to be opportunity in assessing data, such as truck probe data, and in disseminating it.

Through stakeholder interviews, this work identified the best way to disseminate results of demand and supply analytics and found that drivers prefer in-cab, accurate messages about space availability. Disseminating parking availability might be in lieu of or in concert with intelligent transportation system (ITS) device information if it is accurate and in the format drivers need.

More research is needed to evaluate how truck parking scarcity contributes to safety issues such as crashes; however, this research did create an additional platform from which more research in using big data sources can be assessed.

Additional Products

This project aims to deliver education, workforce development, and technology transfer products. This section highlights the products that the research team has completed or plans to complete prior to project completion. These products can be found on the project website (see https://safed.vtti.vt.edu/projects/4610-2/).

Education and Workforce Development Products

Education and workforce development are critical aspects in ensuring that future transportation planners and engineers fully understand the truck parking needs and can use new tools and data to allow for safer truck parking strategies. The datasets produced during this research will also be paramount for the ongoing work conducted at State DOTs, MPOs, and research organizations.

Other deliverables promoting education and workforce development include a PowerPoint summarizing the research findings and a Guidebook in PowerPoint format. The research team plans to use the research findings PowerPoint in several presentations to highlight the benefits and success of this research. Transportation practitioners at State DOTs can use the Guidebook to analyze truck parking in their local areas to evaluate truck parking needs. The research team also plans to submit at least one journal article to highlight the results of this research.

The team has sought and will continue to seek out other opportunities to educate transportation professionals about the safety needs of addressing inadequate truck parking. One successful presentation of the purpose of this research was given to the Girl Scouts of New Jersey. Other opportunities to promote education and workforce development will be pursued when relevant.

Technology Transfer (T2) Products

Technology transfer (T2) is another important component to help transportation planners and practitioners better understand how to address safety related to inadequate truck parking.

Throughout each of the interviews conducted for this project, there was considerable T2, even if the results were preliminary. The research team also plans to conduct several presentations to share the results of the project. Completed and planned presentations include the following:

- Presentation at the I-81 Corridor Truck Parking Technical Roundtable
- Presentation the TTI Technology Conference
- Presentation at the 2023 TRB Annual Meeting
- Additional opportunities as they arise

Data Products

As a result of this project, the following products are available to those who want to learn more about addressing inadequate truck parking:

- Annotated Inventory of Parking Availability Studies and Related Safety Impacts
- Truck Parking Demand and Supply Analysis ArcGIS Map for Howard County, Maryland
- Guidebook to Evaluate Inadequate Truck Parking
- Summary of Findings PowerPoint

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Appendix A: Method for Estimating Demand

Algorithms

To analyze the INRIX data using algorithms, the appropriate form of the data needed to be identified. INRIX provides three forms of data:

- **Waypoint data** (points): individual records of vehicles with position (latitude and longitude) and timestamp.
- **Trips data** (segments): all trips generated from waypoints data. These are identified with a trip ID and are defined by a set of waypoints.
- **Stopping trips** (segments): a subset of trips data, including only those that end with a stop.

The size of the data in any of the three cases represented a challenge for researchers, with stopping trips being the smallest and, therefore, easiest to manipulate. Thus, the initial strategy was to experiment with stopping trips and, if that was not enough to produce results, move on to trips data and waypoints. Figure 2 shows the raw data for stopping trips for Maryland in March 2019.

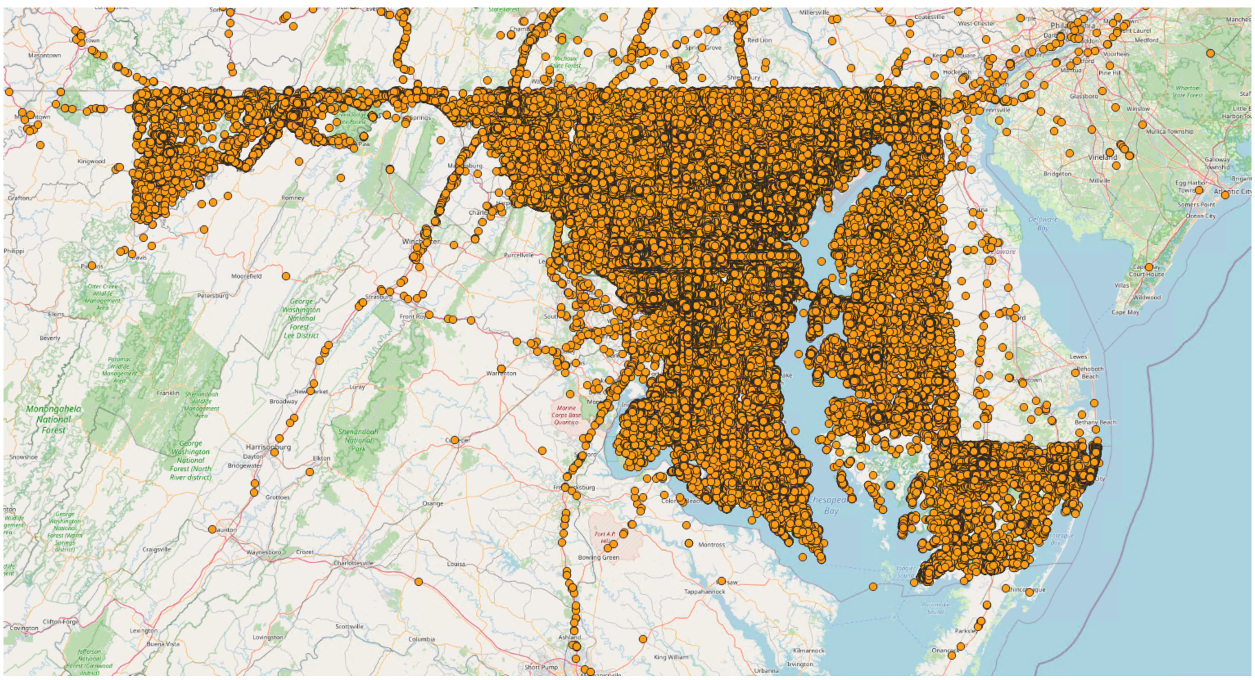

Figure 2. Map. March 2019 INRIX Maryland stopping trips.

Geohashing

Geohashing is a geocoding system that encodes a geographic location into a short string of letters and digits. Each geohash code represents a unique rectangular area. Each extra character added to the geohashing adds precision to the location it represents. For example, a 7-digit geohash represents a rectangle on the earth's surface that is approximately 150 m × 150 m (492 ft × 492 ft) at the equator. Figure 3 graphically shows the concept of geohashing.

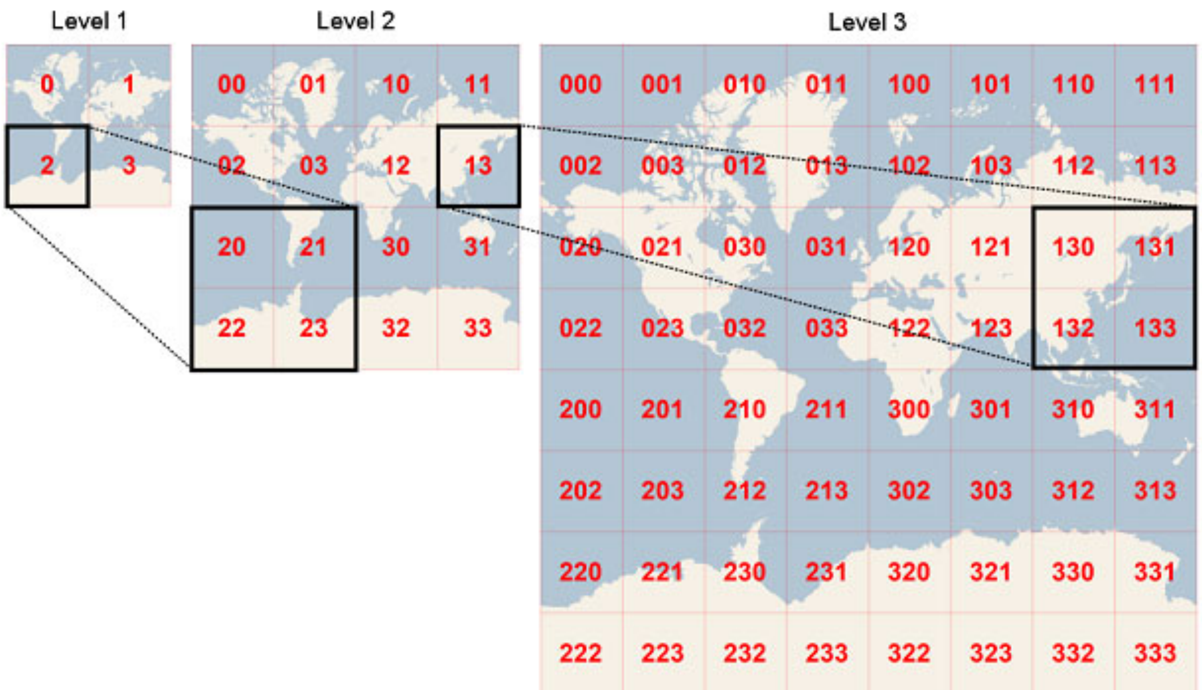

Figure 3. Diagram. Concept of geohashing.

Geohashes are a quick method for transforming large amounts of point data for simplified proximity and location-based trend analysis. Geohashing can be done using existing packages available in modern programming languages such as R and Python. The research team developed a summary table by calculating the total number of stop trips happening in each 7-digit geohash on a specific day of the week (e.g., Monday in geohash dqcp1mt). Figure 4 shows a portion of the resulting summary table. The resulting summary table was imported into GIS software and visualized along with geohashed truck crash information and other relevant data.

Vehicle Type	County	geohash7	Latitude	Longitude	Month	Weekday	Number of Stops	Number of Active Days
3. Heavy Duty	Howard	dqcq7xg	39.110641	-76.833572	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqs49	39.125748	-76.814346	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqsmf	39.143600	-76.801987	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqsz0	39.150467	-76.782761	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqsz8	39.153214	-76.782761	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqut2	39.184799	-76.793747	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcquvp	39.183426	-76.773148	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqv5c	39.176559	-76.770401	March	3. Wed	5	4

Figure 4. Table image. Summary table from Geohashing Step 5.

Reliability Testing

The research team also evaluated INRIX data to see if there was reliability from year to year. This evaluation was a critical step in determining if INRIX data could be used to inform decision-makers about consistent truck parking demand that could then be used to inform where truck parking needs to be added. INRIX data from 2019, 2020, and 2021 were analyzed for the Laurel rest area, a high-demand truck parking location in Howard County, Maryland. Figure 5 shows the Laurel truck parking location. Figure 6 shows the reliability testing results at the Laurel truck parking location. Figure 7 shows the truck parking duration breakdown for 2020 and 2021.

Figure 5. Satellite image. Laurel truck parking location.

2020

Characteristic	N = 2,119[1]
authorized	
authorized	1,344 (63%)
unauthorized	775 (37%)
Parking duration	
1-3 hours	431 (20%)
3-10 hours	339 (16%)
less than 1 hour	1,349 (64%)

[1] n (%)

2021

Characteristic	N = 2,548[1]
authorized	
authorized	1,432 (56%)
unauthorized	1,116 (44%)
Parking duration	
1-3 hours	746 (29%)
3-10 hours	253 (9.9%)
less than 1 hour	1,549 (61%)

[1] n (%)

Figure 6. Chart. Laurel truck parking location reliability testing.

2020

authorized	N	**authorized**, N = 1,344[1]	**unauthorized**, N = 775[1]
Parking duration	2,119		
1-3 hours		237 (18%)	194 (25%)
3-10 hours		209 (16%)	130 (17%)
less than 1 hour		898 (67%)	451 (58%)

[1] n (%)

2021

authorized	N	**authorized**, N = 1,432[1]	**unauthorized**, N = 1,116[1]
Parking duration	2,548		
1-3 hours		347 (24%)	399 (36%)
3-10 hours		159 (11%)	94 (8.4%)
less than 1 hour		926 (65%)	623 (56%)

[1] n (%)

Figure 7. Chart. Laurel truck parking location parking duration breakdown.

Appendix B: Method for Estimating Supply

To develop a method to identify truck parking opportunities, the research team focused on Howard County, MD. Areas were chosen based on the clustering algorithm, number of truck-related crashes that occurred near the area, and their uniqueness compared to one another.

Areas observed:

1. Laurel Welcome Center – This is already a well-established, publicly-owned truck parking area. Is there more area available to create more spaces there? What else is nearby?
2. Intersection of MD 32 and I-70 near West Friendship – This is a more rural area than the others. What challenges could this cause? Is it likely more spread out?
3. Waterloo and Jessup Area – A major industrial/commercial area that can provide a good view of how to qualify privately owned parking lots that are underutilized.
4. Intersection of MD 100 and US 29 near Autumn Hill – Two major roads that intersect near a shopping/residential area. Another type of privately owned land to observe.

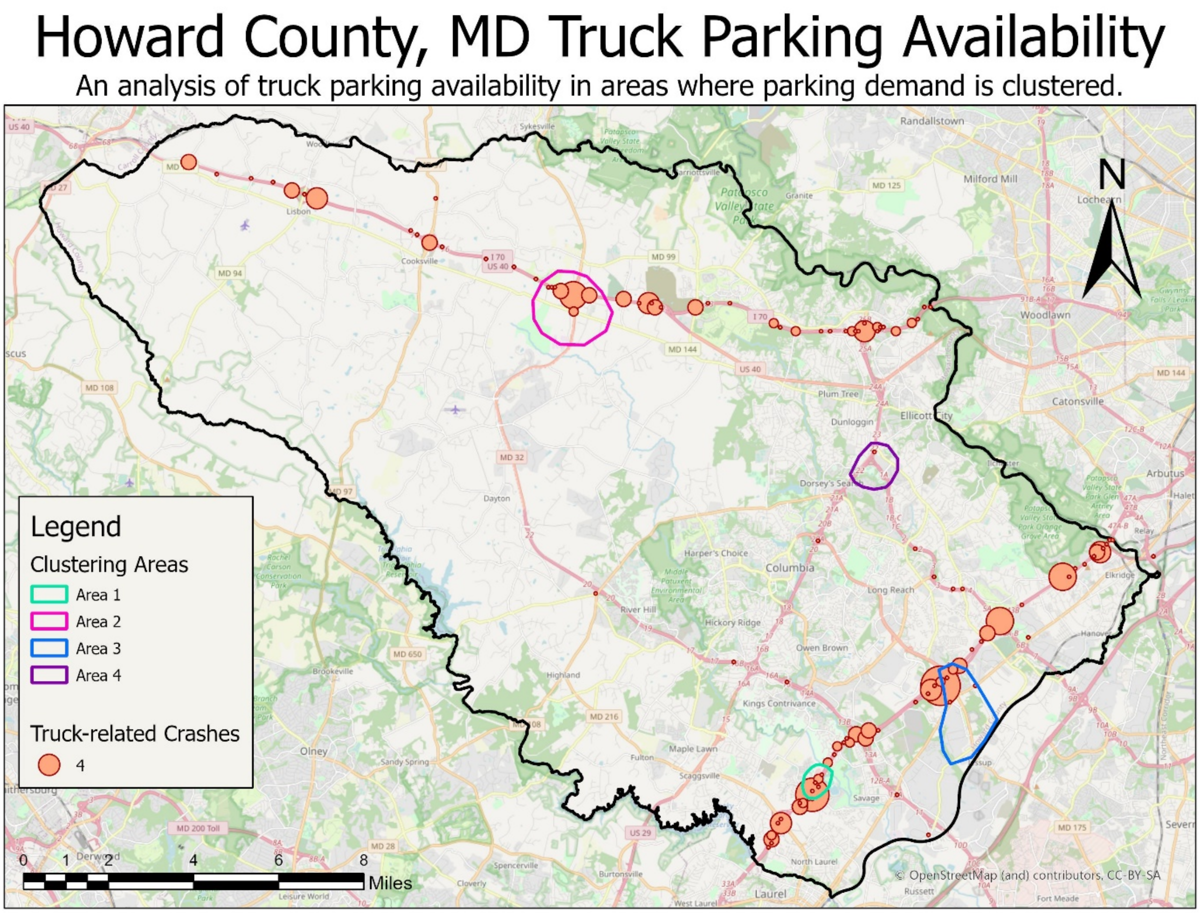

Figure 8. Map. Truck parking clustering areas and truck-related crashes in Howard County.

Data layers were sourced from publicly available databases, including Maryland's GIS database and the Chesapeake Conservancy. Using the Suitability tool, the layers reclassified in the previous step were added together, and each was provided a weight based on how a real-world analysis might consider these layers against one another:

- Land Ownership: 40%
- Land Use/Land Cover: 20%
- High-Res Land Cover: 20%
- Terrain Ruggedness: 20%

In the result of this tool, a new layer was created that shows the suitability of a given area in Howard County (see Figure 9).

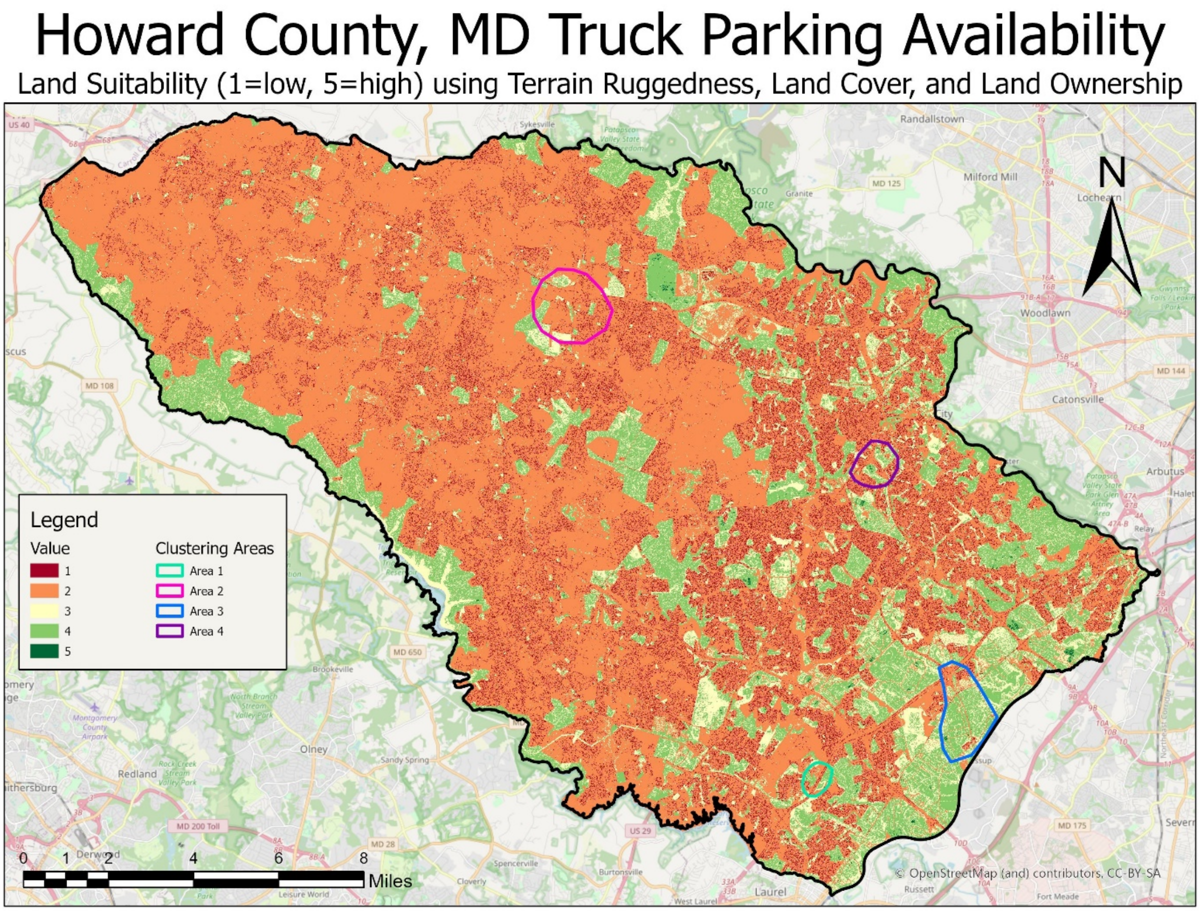

Figure 9. Map. Resultant map of the suitability analysis, using Land Use (20%), High-Res Land Cover (20%), Land Ownership (40%), and Terrain Ruggedness (20%) as parameters.

To provide a more useful level of information, the VTTI research team used Zonal Statistics to find the average suitability value over each parcel in the Land Ownership layer. These values were then spatially joined with the relevant parcel in the Land Ownership layer (see Figure 10) to take the values from the previously created raster layer and relate them to the layer over which they were averaged. This now allows for the Land Ownership layer to be filtered by their suitability value. In this analysis, all values below 3 were filtered out, as anything at this value is likely not of interest.

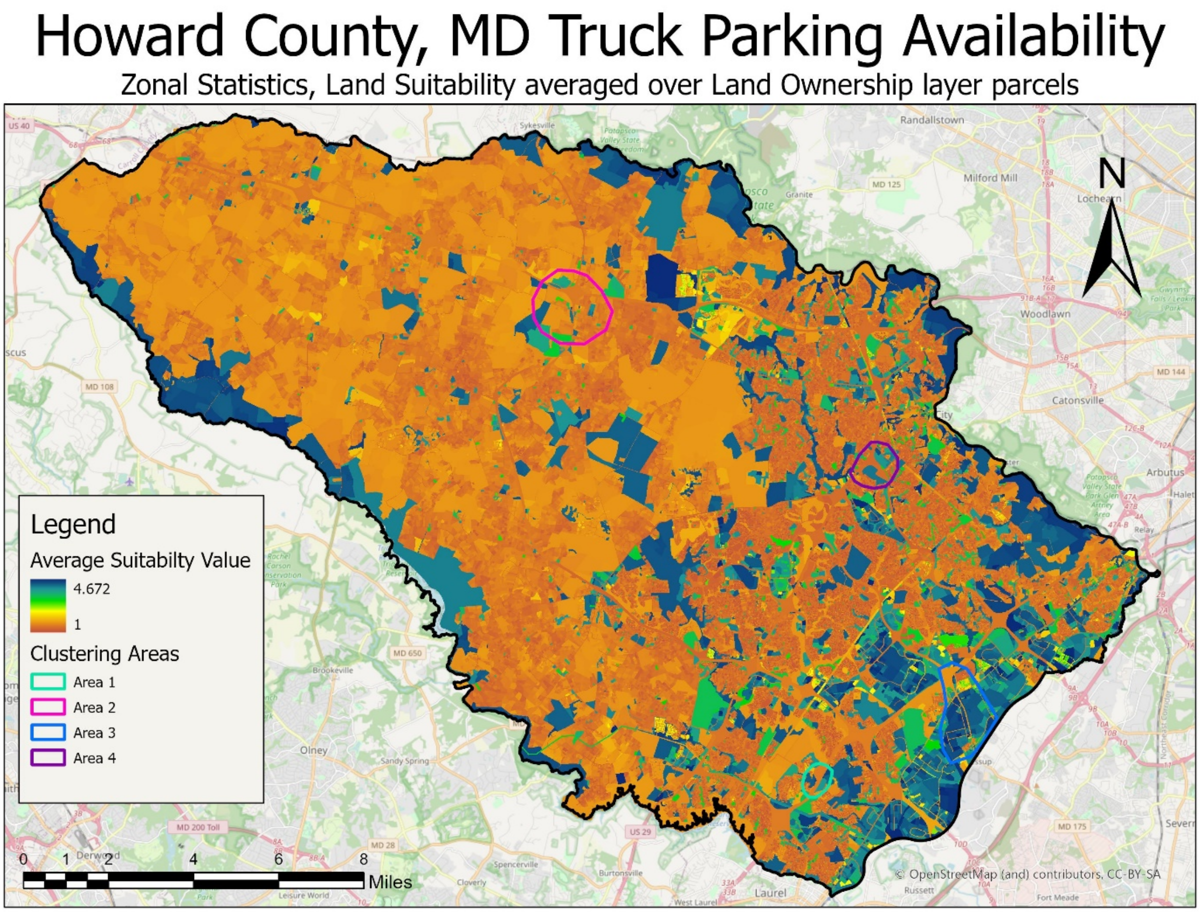

Figure 10. Map. Land Suitability raster, averaged over each parcel within the Land Ownership layer.

Appendix C: Key Findings from Stakeholder Interviews

Truck Parking Preferences for Different Types of Truck Drivers

- Less Experienced vs. More Experienced Drivers
  - More experienced drivers already know the rest areas they prefer to park at through their experience and use Trucker Path to see whether spots are available before pulling into a rest area.
  - Younger drivers are better at technology than the older drivers.
  - The older drivers are very slow to adapt to new technology. There is a lot of fear attached to trying something new.
  - Older drivers prefer roadside signage close to parking locations, while younger drivers prefer to rely on apps, parking on shoulders and checking online status parking availability at truck stops where they want to go.
- Male vs. Female – Truck Stops vs. Rest Areas
  - Women drivers generally do not prefer truck stops because of the high crime rates where they are located.
    - They prefer to spend the night on site at a customer's parking lot (shipper or receiver) because it is secured with gates and cameras.
    - Next to that, they prefer rest areas due to safety concerns. Plus, there are more trees and open spaces for walking dogs.
  - Truck parking spots are often not lit at night. Without any security, these spots are unsafe, especially for female drivers. In addition, there is nobody to take concerns to when something goes wrong.
- Fleet Drivers vs. Independent Operators
  - Trucking companies will require their drivers to rest/park at specific truck stops because they have fuel discounts and other deals worked out with those truck stops.
  - Truck company fleet drivers cannot just fuel wherever they want. They must go where the company tells them to go and that company will give out driver points.
  - Some companies are specific about which truck stops to stop at due to the nature of cargo, such as pharmaceuticals or other high-value cargo. A lot of companies give out a list of truck stops that are dangerous and have high crime rates.
  - Independent owners will hunt and pick.
- Free vs. Paid Parking
  - Drivers prefer to reserve parking by paying for it in advance.

Technology & Communication Preferences

- *Questions*
  - What are the best (e.g., safest, most effective) in-cab connected vehicle (CV) information dissemination technologies to share truck parking information?

        - What has been shown to be least effective in disseminating truck parking information?
    - Lessons learned in their CV pilot deployments and providing in-cab information
        - Practical experience in trying to deploy CV technology in-cab to truck drivers
    - What are the one or two CV technologies that should be used for providing real-time in-cab information on parking availability?
        - Why?
    - What is your assessment of the maturity levels of CV technologies? e.g.,
        - Drivewyze
        - ELD CE-Road
        - Smartphone
    - What are the data privacy/security and cost implications of each?
    - Are there coverage shortages for any?
    - What kinds of information are important to send and receive?
    - What kinds of information are irrelevant to truck parking?
    - What are specific messages and messaging types that truck drivers would prefer?
- *Parking Detection Preferences*
    - Florida DOT installed pucks to detect trucks at entry and exit points to collect data on truck parking. They also used a video analytics system where AI was used to collect data. However, these technologies fail in extreme conditions such as rain and snow. Plus, the costs are exorbitant (each video camera can cost up to $30,000).
    - Some other technologies that have been tried are radar and sensors that can be pole mounted.
    - WSDOT installed sensor pucks that provided 99% accuracy of parking availability, but the pucks have a 10-year life span, which is a concern (i.e., maintenance costs of replacing them). Therefore, they are working with information technology providers and app developers to pull the data they collect. Currently, they are facing bandwidth issues because of big data to make it real time.
    - Truck Parking Services pilot used federal grants for a project where they installed sensors in each parking location that counted in-and-out movements. It was very accurate and inexpensive.
- *Information dissemination technologies: In-Cab (Phone apps, ELDs) v. Outside Cab (Signs)*
    - **Apps, Google, GPS, 511**
        - Apps commonly used, including Trucker Path, Google Maps. However, this violates phone/hands-free policies and laws.
            - Drivers are not supposed to be touching their phones when they are driving but forced to do so for checking the weather, availability for food, etc.
            - In terms of safety, drivers need to use one app rather than change 50 apps when they cross a state border.
        - Google: Female drivers often look up Google reviews of truck stops before stopping to make sure it is safe to stop there.
            - Truck drivers are good at providing honest feedback through Google reviews.

        - If there is a delivery or pickup at an odd hour and no parking available at those times there or in the surrounding area, drivers will go to Google Earth and zoom down into their location to find a street or somewhere safe to park.
    - GPS: Other drivers use GPS devices (such as Garmin) to show where truck stops are located while they are driving.
    - 511 Sites/Apps: Some drivers use 511 to check for weather updates, but not really for truck parking availability.
- **Trucker Path Mobile App:**
    - Advantages of Trucker Path
        - Has crowdsourced information, which is helpful to drivers to decide whether a truck stop is worth stopping at (however, crowdsourcing makes the app not fully reliable).
        - There are about 20,000 truck parking locations identified on the Trucker Path app that are geofenced around the country (48 states). All contain information/data provided by the driver community.
        - The app has about 1 million active users every month, which is about 30% of the long-haul market.
        - The Trucker Path app has a navigation, weather, load board service, transportation management system, and new dispatch service (recently launched).
        - Trucker Path has a "Forum" button where drivers post their input to improve the app. This section is monitored by Trucker Path, and they try to resolve the problems to the best of their ability.
    - Trucker Path is the go-to for drivers
        - Drivers find that Trucker Path has done a really good job of setting up the app, though there are some missing things that could be better.
        - Drivers are annoyed that they must pay to access Premium features (e.g., truck parking prediction).
        - It has all the features that drivers need. It lets users map point to point just like Google Maps and truck stops on the way.
    - Truck Parking
        - Trucker Path app gives real-time information and uses historical data to predict parking (using machine learning).
        - The app shows parking availability by time and day of the week.
        - Trucker Path indicates whether truck parking is likely to be available based on that crowdsourced information.
        - The app has visuals to explain the type of facility on the map. For example, T stands for truck stops, P stands for parking. Drivers can check out the location images posted by the community and read reviews.
        - Drivers will trust other driver reviews on the app. Drivers make their decisions based on reviews they read from the app.
        - Trucker Path communicates three options for the likelihood of finding truck parking at a given location: very likely (green), somewhat likely (yellow),

        - or full (red). This feature is now a part of Trucker Path's premium (paid) product. This predictability is based on historical data.
        - Trucker Path has multiple language selection options available. Spanish is the most used language after English.
        - Trucker Path also provides information about Walmart locations that let trucks park overnight. Usually, Walmart limits truck parking to 8 hours.
        - Trucker Path gives locations of rest areas, hotels, Walmarts, casinos, and truck stops, and it provides the ability to reserve parking at some locations.
    - Trucker Path could benefit from truck parking availability information from states if the data were available by API.
    - Trucker Path is willing to provide states aggregated truck parking data and adoption demographic data.
- **ELD**
    - Having truck parking information on ELD would be helpful. All in one is best for the driver.
    - However, different truckers use different ELDs and different ELD software, so a limitation with providing truck parking information via ELDs is that the messaging will not reach all drivers.
    - Technology is not there yet to provide truck parking information.
    - Just like with regional tolling systems (e.g., EZPass), there should be a centralized hardware system that provides all the information drivers need, including truck parking. Different technologies will not work.
- **Trucking Company Proprietary System** (USXpress/Variant)
    - Variant is applying digital technology to trucking as the seventh-largest over-the-road trucking company with 2,600 drivers in the fleet and 5,000 seated trucks.
    - USXpress is trying to build their own terminal network and deploy their own kind of infrastructure and expand it rather than use what is available in the market.
    - USXpress collects a lot of data within its system because of their large fleet size. They have historical data, live stream data, and other data—more than Trucker Path has.
    - USXpress has a strategic partnership with Love's truck stops where their trucks fuel and stop.
        - They do not reimburse drivers for parking because with their technology, drivers should be able to find parking.
        - They are trying to negotiate with Love's to pay and reserve parking spots on a monthly or annual basis.
    - They have their own fuel routing system using ELDs, mobile app, and platform science (i.e., tablets with Variant's proprietary web-based, cloud-based telematics and ELD tool).
        - Platform science = each driver is provided a tablet device (different from ELD) that can access their routing/fueling/parking app, scan bills, etc. However, they can use their mobile phone, too, if needed.

        - ELDs used as a telematics tool to track their trucks.
        - Drivers can see fuel stops, rest areas, and truck stops using the mobile app, but they cannot see the number of parking spots available.
        - Availability of parking spots is accessed through Google or word of mouth for the most part.
        - Variant is developing their own truck parking information tool.
    - USXpress uses shipper APIs, which have real-time analytics pricing for freight. They are also developing tractor APIs.
    - Government should be more focused on collecting information from public facilities but should provide API that distributes information on both public and private truck parking spaces.
- **API:** most useful based on interviews
    - Drivers will not access 50 different apps or 511 sites. They will use their preferred app to know where to park, eat, shower, and sleep. It does not make sense for a State DOT to create an app or website to display truck parking information. It will not be used.
    - Private tech companies (e.g., Trucker Path) would incorporate truck parking availability data from states, preferring a common API language like what FHWA offers through the work zone data exchange (WZDX).
    - For example, MDTA developed an interactive online map that shows where truck parking is, but drivers did not use it. It is mainly used by commercial operators for route planning purposes within the company.
    - Truck stops will not say they are full, so collecting truck parking availability data from them will be challenging. Thus, the public sector should focus on providing availability information for their (public) truck parking spaces via API. Private sector tech companies will develop a solution for providing availability information for private spaces.
- **Outside Cab (Signs)**
    - Signs are helpful when they show availability within a close distance—5 miles or nearer. Further than that, the information is not useful because by the time a driver arrives, the parking may not be available anymore.
    - Sometimes signs are problematic when they do not display the right information. Accuracy and reliability are important when disseminating information to drivers.

Information Preferences

- Questions
    - What is required and desired content of the messages about parking availability among truck drivers?
    - What are parking information preferences, including conforming (or not) to CV technology options?
- Signs

    - In some truck drivers' opinion, the government spends too much money on roadside signs and not enough on creating more parking spaces. When these signs malfunction, nobody takes responsibility to maintain them.
    - Some roadside signs will mention that there are "low," "moderate," and "high" levels of available parking, but drivers want to know the exact number of spots, so they do not pull inside a full parking area and waste their time.
    - In addition to permanent roadside signs, drivers think there should be portable signs that communicate things like weather-related incidents for drivers to plan their response ahead of time.
    - There is a need for messages with different languages to accommodate all cultures.
    - It would be helpful if every state used rest area signs that tell drivers exactly how many available parking spots there are. Drivers need real-time information about parking, facilities, amenities, etc. This should be a nationwide effort for the sake of drivers.
    - Iowa and Indiana deployed truck parking information projects where road signs showed upcoming rest areas and the number of parking spaces there.
    - Wisconsin has rest area signs that tell drivers that are 5 to 100 miles out about how many parking spots are available in each rest area. Some of these signs are very accurate with numbers at even 2 a.m.
    - Drivers prefer that signs indicate how much parking is available at exits/rest areas that are relatively nearby (within 5 miles). If a sign provides the number of spaces that are 25, 50, or 100 miles down the road, trucks ahead might take up all the available spaces by the time the driver arrives.
- Trucker Path
    - The major problem with the Trucker Path app is that drivers need to use their phones to check whether there is parking ahead, which can be dangerous while driving.
- Key Information
    - If rest areas or weigh stations are demolished or not closed for any reason, this information should be provided on websites and apps, or via notifications to drivers (e.g., signs near the exit ramp). Drivers find it highly frustrating when they arrive at a location that they cannot park at and realize there is no place to park nearby.
    - Drivers want to know what facilities and amenities are present at the truck stop so they can choose if they want to stop at that place or not. There should be a minimal number of words to display and convey the information most successfully without distraction.
    - Drivers typically drive 11 hours a day. They need parking information at least 2 hours before they decide to stop for the day because it may take about 2 hours to find parking along highways. Drivers will have to drive more than 11 hours when there is no place to park, and company policies do not allow them to park on shoulders.
    - Trying to find truck parking late at night (after 9 p.m.) is a big problem as most places are already full.
- Apps
    - States should build on what is already out there. There should be one system to show truck parking, one app for everything (truck parking, logs, routing).

    - States should provide open-source data for state-owned parking availability that is accessible (via Trucker Path and other apps) to everyone for free. Trucker Path and others can charge the premium price for other private truck parking information.
- ELDs
    - If ELDs provide truck parking information, drivers think they should display minimal information (e.g., "Truck parking/rest area/weigh station 2 miles away" providing the number of spots available there) as a pop-up to avoid distracting the driver. Simple and minimal information works best. Perhaps there could also be an option to pull over and open an app for more information on facilities and amenities.
    - Drivers think there should be a system on ELDs where drivers can input the route they are driving for the day and be notified of truck parking, rest areas, restaurants, and weigh stations through pop-ups on the way for both short and long breaks. It would be helpful to new and experienced truckers.
    - Drivers think ELDs should show, along with tracking time and route, real-time information about rest areas ahead.
    - Currently, ELDs tell drivers about how much more time they must drive (e.g., "You are 'xyz' far from violating HOS rules"). It would be helpful if they could provide information on upcoming truck stops, how many spaces there are, and any traffic updates.

State DOT Experiences with Truck Parking

- *Georgia DOT*
    - ELD (Georgia DOT Drivewyze Pilot)
        - Ran pilot program with Drivewyze where drivers receive rollover notifications from predetermined spots in Atlanta region. There were 10 pilot locations. The pilot program ended in 2020. In that pilot, truck drivers with Drivewyze on their ELDs who entered the zone were notified with safety messages. When they exited the zone, speed data were collected.
        - Only commercial motor vehicle drivers enrolled in the Drivewyze safety notification program received safety messages, and not every vehicle. About two thirds of drivers received notifications and one third did not receive notifications from Drivewyze.
        - After assessment of 2020 ELD notification data, GDOT found fewer incidents in some locations due to the notifications (though they were not sure whether they could claim if the findings were due to the notifications alone; they do not have substantial evidence).
        - ELD notifications were designed to display only one notification at each location (per approach of an interchange) to avoid confusion from too many messages popping up.
        - In theory, they should be able to display more notifications—including truck parking information—to warn of hazardous conditions along the route.
        - GDOT supports the pilot with Drivewyze and there is a high chance that GDOT will move forward with it in coming years.

        - Currently, there is no truck parking information signage from GDOT on highways.
        - In Georgia, state highway patrol has authority to check ELD or logging book anytime.
    - Addressing truck parking from an ITS/operations perspective (but no specific expansion program).
        - GDOT has discussed internally partnerships with private truck stops and bigger gas stations to try to communicate truck parking information on highway message signs on interstates and highways and let drivers know how many parking spaces are available at their facilities. This is still an idea that is being discussed.
        - GDOT is in talks to install radar detection technologies that can count the number of parking spots within a certain zone. However, the deployment would require maintenance.
        - GDOT has an ITS maintenance contract they could tap for parking detection and communication, but this is still in the conversation stage of development as there is no simple solution.
        - GDOT is not really interested in using pucks to detect parking availability due to maintenance issues and replacing them every few years.
- *Maryland DOT*
    - Oversize/Overweight Routing Program
        - MDOT recently made updates to their oversize/overweight routing system (Maryland One). Maryland One is a "Bentley transportation program" customized for Maryland that was developed primarily for oversize/overweight vehicles to indicate to drivers the correct route based on their permit. This system autoroutes when truckers change their travel path and tells them exactly where to go for their size, weight, height, and over dimensional loads. It also lets drivers input start and end points (also middle point if they want) of their route or choose on the map (just like with Google Maps) from all possible routes. The app is open to the public once a user creates an account. Even drivers not needing permits, such as farmers and boat owners, have used the program to know the adequate routes to take.
        - MDOT is currently working on developing an app from the Maryland One routing program. Once people enter their permit number, the app will speak directions to them while driving. Even if a truck driver goes off route, it will reroute and give them alternate routes. They are also going to add weather data to the app.
    - Websites (Maryland DOT)
        - MDOT used its 511 website for communication but its usefulness has diminished over time.
        - MDOT's CHART website has traveler information, live cameras, interactive maps, traffic incident and events notices, speed sensor data, and highway message sign information.

- Emergency Parking
    - There are scale houses near the state line where trucks park during nighttime in case of emergencies such as snow. They are allowed to park when the station closes and must move when the station opens in the morning.
- *Maryland Transportation Authority (MDTA)*
  - Truck parking available at rest area facilities: MD House, Chesapeake House, Inspections Scale Houses
    - There are many truck parking lots in rural areas about 50 miles north of Baltimore that go empty because drivers want to park close to city limits to deliver goods. Therefore, they park illegally in the city.
    - MDTA is trying to develop more scale houses and rest areas in Maryland due to high demand, but development is slow due to the time it takes to get environmental permits.
  - Signs: Ran a pilot where they put up dynamic message signs with messages saying "Exit 53 has xyz truck parking" to attract truckers into facilities. When the system became popular, they used highway advisory radios. They also experimented with Waze and a few other tech platforms.
  - Parking Inventory: MDTA conducted private truck parking inventory and has asked private truck parking owners to communicate and let them know when they are full to avoid trucks turning around without parking.
  - ELD/Drivewyze: MDTA has a contract with Drivewyze for weigh stations and hopes the company can include communication of safety information (not yet deployed).
  - 511: Pennsylvania DOT developed a 511-system app that is geofenced and communicates to drivers about roadway incidents. Drivers can also send messages through that app to notify authorities of medical emergencies, for example, and their need for help.
    - MDTA is trying to develop a similar app to disseminate such roadway incidents and weather conditions.
  - API: API is preferred because truck parking information should be disseminated by the private sector. Government agencies cannot keep up with the different communication systems (ELD, Trucker Path, etc.).
- *Washington State DOT*
  - Pilot Generally:
    - WSDOT is currently deploying a truck parking detection system and developing an API where they can make the data available to the public and third-party app developers.
    - The project is a means of managing the existing (public truck parking) inventory.
    - WSDOT performed a pilot project in 2019 that used in-pavement puck sensors to detect available parking spots at locations. These data were fed to a predictive algorithm. This information was then sent to an Android app and website.
  - Detection:

        - WSDOT received a grant from FMCSA to expand the pilot program (up to 2025). With this grant, WSDOT is working on researching alternate detection systems that do not present the same asset management concerns as pucks, including vision at entry and exit (radar systems), spot prediction, and spot-based detection systems. The evaluation of these methods is in progress.
    - Prediction:
        - The pilot project is being deployed in partnership the University of Washington (UW), which is developing a predictive algorithm to estimate how much parking will be available by the time the driver arrives at the location. UW is studying historical behavior for truck parking and predicting (most likely) availability of parking in the future (at locations at times).
        - UW developed the proof of concept and has been able to predict availability 4 hours ahead of time with about a 12% error in their prediction. They used machine learning algorithms for their detection.
    - Communication:
        - The problem with roadside signage is that if the driver did not read that sign on time, there is no other way to go back. Hence, WSDOT is trying to have that information available continuously and when the driver wants it through API.
        - WSDOT is focusing on API to share with private vendors (Drivewyze, Google, and other third parties) to disseminate through their systems.
        - The pilot program app tells drivers about the availability of parking spaces from 10 minutes to 4 hours ahead of their location and the confidence they have about the prediction in the form of a ranking system (very likely, somewhat likely, and less likely).
    - Limitation of Pilot:
        - The parking detection and communication is only for public facilities in Washington State (rest areas, truck stops, and weigh stations).
        - No private parking information is provided. Private companies showed interest in participating in the project at the beginning, but now seem disinterested. They may be concerned that if they let drivers know that parking is not available at their facilities, it will harm their business model/profits.
    - Other WSDOT Truck Parking Efforts
        - There is a new state requirement to map out all (public and private) truck parking locations. WSDOT has been focused on improving getting truck parking information out to the public.
        - There are discussions with private partners about starting up new truck parking lots and WSDOT leasing private land for truck parking (going to build in next 5 years).
        - WSDOT is collaborating and coordinating with neighboring states (California, Oregon, Idaho, Montana, Utah) to share truck parking data and develop a standardized common platform.
            - Truck parking is not only a state issue, but also a regional and national issue that needs to go beyond the state borders.

        - Statewide Freight Plan
            - The SFP's truck parking component contains an inventory of private parking spots.
            - The SFP's truck parking findings were based on INRIX data they purchased.
            - WSDOT conducted supply chain studies to identify where drivers park. They found where drivers parked (legal and illegal spaces) and, thus, where more parking was needed. They found more parking was needed near ports and warehouses. The study showed the demand and supply ratio in the state, which was incorporated into the current Statewide Freight Plan. Best and probable solution to this demand will be to expand current truck parking, but the underlying problem is funding.
        - Other efforts include outreach: conducting workshops, talking to MPOs and cities.
        - WSDOT's dedicated truck parking efforts involve:
            - Maintenance (of rest areas)
            - WSDOT Safety Rest Area Plan
            - CAV effort
            - WIM/e-credentialing
- *Wyoming DOT*
    - WYDOT Website and 511
        - Truck parking information is provided on WYDOT's website (1.6 billion web hits in 2019), 511 Notify website (about 11,000 subscribers, 27 million messages), and 511 mobile app (over 300,000 downloads).
        - The mobile app gives parking availability information (whether there are a lot of spaces, few spaces, no spaces). They do not report actual numbers. Whenever someone reports the parking availability data, the app updates for everyone automatically. Crowdsourcing data are used.
    - Detection
        - WYDOT tried a radar system in the past to count parking.
    - API
        - They have API available for anyone to use for their own purposes. WYDOT prefers to make API available rather than invest in app/website development or sign installation because the private sector will communicate the information more quickly and effectively.
        - API is used to communicate information such as variable speed limit speeds, rare conditions, and road closures due to weather or construction.
        - It would be beneficial if states can collect their parking data and push it to one common platform using one common data language for third parties to use and send to drivers rather than each state having separate apps.
    - Signs
        - WYDOT deploys dynamic signage within a mile of public truck parking areas.
        - They are getting information from speed sensors (a low-cost solution).

        - WYDOT deployed a pilot supported by federal grants, which installed roadway signs. Some are still being constructed. WYDOT's intent was to deploy the most cost-effective measures using the grant money.
- *Texas DOT*
    - Detection:
        - This is still in the procurement process for detection technology that will be used for their truck parking project.
    - Signs:
        - Their intent is to disseminate truck parking information through dynamic messaging signs and the blue highway signs showing the number of available parking spaces.
    - Website:
        - Apart from dynamic messaging boards, parking information will also be shared on the drivetexas.org website.
    - Regional Efforts
        - TxDOT is trying to work with New Mexico DOT to install similar signage in their state and share data.
        - The FHWA ATCMTD grant is helping to fund a total of 37 parking sites along I-10 from Texas to California. There are 18 truck parking sites, six safety rest areas, and two travel information centers located in Texas.
            - There will be a truck parking facility (currently in design phase) located near I-10 to address traffic issues.
        - Texas is working with the Institute for Trade Transportation Studies and other southeastern neighboring states to discuss freight planning issues.
        - There are talks with regional partners about how to streamline truck parking, oversize, overweight permits, etc. across states.
    - Coordination with Locals and Private Sector
        - TxDOT plans to work with local municipalities and leverage public-private partnerships to expand or build truck parking in urban areas of Texas.
    - Maintenance:
        - Maintenance is ongoing at few parking facilities.
    - 2020 Statewide Truck Parking Study
        - 2020 Statewide Truck Parking Study is complete.
        - It found a major problem in the state not having enough truck parking. There are a total of 2,200 truck parking locations in Texas. About 4 million trucks crossed Laredo alone last year. Because shippers and receivers provide appointment times to drivers, trucks cannot be late or arrive early. As such, they park on the side of the road, causing traffic and safety problems.
    - Concerns
        - There is a lot of cutting-edge technology, but lack of infrastructure is the problem. For example, they will be able to detect the number of parking spaces, update them, and communicate that information, but connectivity issues in rural areas with no signal will undermine the effectiveness of the program.

- Another problem is how that information gets inside a truck.
- A lot of companies do not want drivers to use cell phones while driving. They want to disseminate information by some in-cab system and use the signage on the road.

Appendix D: ArcGIS Static Images

The research team decided that an important product of this section was to develop an interactive map of the data. Therefore, the team created an ArcGIS online map with all the data layers so that readers of this study and future researchers can explore the data in detail and replicate the analysis. The link for this map shown in Figure 11 is: https://arcg.is/0rHnGH.

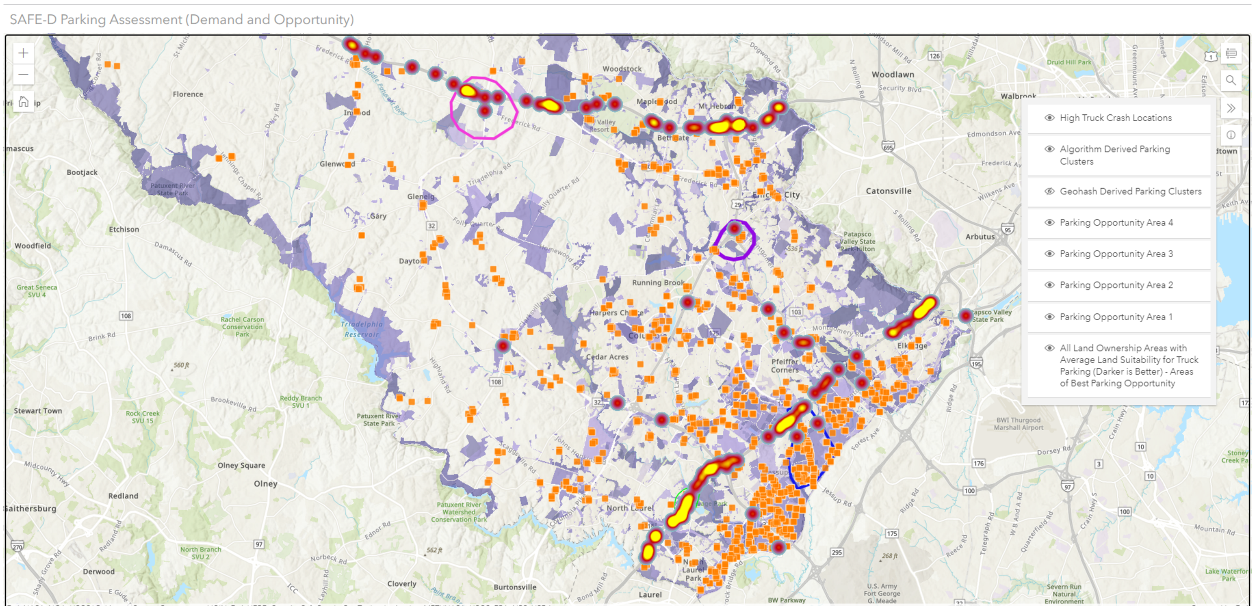

Figure 11. Map. Final output showing truck parking demand and supply.