

Truck Parking Needs in Tennessee

Prepared by:

Principal Investigator

Mihalis Golias, Ph.D.

Professor, Dept. of Civil Engineering, University of Memphis, 104B Engr. Sc. Bldg., 3815 Central Avenue, Memphis, Tennessee 38152, Tel: 901-678-3048, Fax: 901-678-3026, Email: mgkolias@memphis.edu

Co-Principal Investigators

Sabya Mishra, Ph.D., P.E.

Associate Professor, Dept. of Civil Engineering, University of Memphis, 112D Engr. Sc. Bldg., 3815 Central Avenue, Memphis, Tennessee 38152, Tel: 901-678-5043, Fax: 901-678-3026, Email: smishra3@memphis.edu

Christopher R. Cherry, Ph.D.

Associate Department Head of Undergraduate Studies and Professor
University of Tennessee, Department of Civil and Environmental Engineering, Center for Transportation Research Fellow, 321 JD Tickle Building, Knoxville, Tennessee 37996-2313, E-mail: cherry@utk.edu

Airton Kohls

Research Associate III

Center for Transportation Research, University of Tennessee, 309 Conference Center Building, Knoxville, Tennessee 37996-2313, E-mail: akohls@utk.edu

Daniel Murray

Vice President, American Transportation Research Institute

2277 West Highway 36, Suite 302, Roseville, MN 55113

Email: dmurray@trucking.org

Graduate Research Assistants

Dimitrios K. Giampouranis

Dept. of Civil Engineering, University of Memphis, 104 Engr. Sc. Bldg., 3815 Central Avenue, Memphis, Tennessee 38152, Email: dkgmpns@memphis.edu

Vasileios Liatsos

Dept. of Civil Engineering, University of Memphis, 104 Engr. Sc. Bldg., 3815 Central Avenue, Memphis, Tennessee 38152, Email: vsliatsos@memphis.edu

December 9, 2020

DISCLAIMER

This research was funded through the State Planning and Research (SPR) Program by the Tennessee Department of Transportation and the Federal Highway Administration under **RES #:2019-16, Truck Parking Needs in Tennessee.**

This document is disseminated under the sponsorship of the Tennessee Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Tennessee and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the views of the author(s) who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Tennessee Department of Transportation or the United States Department of Transportation.

Technical Report Documentation Page

1. Report No. RES 2019-16	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Truck Parking Needs in Tennessee		5. Report Date November 2020	
		6. Performing Organization Code	
7. Author(s)		8. Performing Organization Report No.	
9. Performing Organization Name and Address University of Memphis 3851 Central Avenue Memphis, Tennessee 38152		11. Contract or Grant No.	
		13. Type of Report and Period Covered	
12. Sponsoring Agency Name and Address Tennessee Department of Transportation 505 Deaderick Street, Suite 900 Nashville, Tennessee 37243		14. Sponsoring Agency Code	
		15. Supplementary Notes	
16. Abstract <p>The scope of this research project was to extend the work by Golias et al. (2017) and Cherry et al. (2017) and collect and process truck, network, and rest area data; develop, distribute and collect, synthesize and analyze a truck parking survey; develop extrapolation factors and estimate truck parking utilization and violations (i.e., truck parking at on- and off-ramps); and develop and apply a methodology to identify existing locations that require capacity expansion and locations for new truck parking facilities in the State of Tennessee. Fifteen existing rest areas were identified as candidates for capacity upgrades, and two segments of the interstate network (I-40 between Jackson and Nashville and I-75 north of Knoxville) as candidates for construction of new rest areas. Results revealed that technology investments to provide real time truck parking availability would further support balance of truck rest area supply and demand. The research developed one desktop and two web-based tools that allows further data analysis to be performed to support HOS compliance, reduce unauthorized truck parking, improve safety, and support budget allocation for truck rest area enhancement and enforcement in Tennessee. This study can be a key component for freight planning and investment activities, as well as a template on how to utilize GPS data to produce various performance measures regarding truck parking.</p>			
17. Key Words TRUCK PARKING, CAPACITY EXPANSION, GPS DATA, DATA ANALYTICS		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 57	22. Price

Executive Summary

The freight transportation system in the United States is one of the cornerstones of economic prosperity and heavily relies on efficient transport by road. Long term economic growth, as well as the nation's dramatic shift to e-commerce, is expected to result in even greater demand for truck traffic transportation. The latest version of the Freight Analysis Framework (<https://faf.ornl.gov/faf4>) projects truck traffic in the US to increase by 30 percent by tonnage and 60 percent by value by 2045 and account for 65 percent of the total freight movements (both by tonnage and value).

Whether needed for staging, pick-ups & deliveries or hours-of-service compliance, truck parking is a critical component of supply chain operations. However, there is a huge gap between the demand and supply of truck parking facilities in many states. Other limiting factors include limited road networks, municipal truck parking restrictions and declining infrastructure investments, all of which puts considerable constraints on a truck driver's ability to deliver goods safely, legally and on-time. When inadequate parking exists, truck drivers are often forced to park in unauthorized and/or dangerous locations, creating new hazards for both the truck driver and motoring public. Recent research by the American Transportation Research Institute documents that truck drivers now need to sacrifice revenue drive-time to commence looking for truck parking, which could exacerbate both the truck driver shortage and entice drivers to later speed to make up for lost wages. To understand and ensure proper utilization rest area truck parking at specific periods of time, research was needed to understand utilization during different time periods and the factors associated with this utilization. Furthermore, research was needed to understand and quantify parking violations (e.g. parking on on- and -off ramps) and at the same time develop a methodology that would allow decision makers in identifying locations for new truck rest areas.

This study extended the work done by Golias et al. (2017) and Cherry et al. (2017) who used truck GPS, direct observation, and survey data to evaluate the performance of truck parking in Tennessee. The scope of this research project was to collect and process truck, network, and rest area data; develop, distribute and collect, synthesize and analyze a truck parking survey; develop extrapolation factors and estimate truck parking utilization and violations (i.e., truck parking at on- and off-ramps); and develop and apply a methodology to identify existing locations that require capacity expansion and locations for new truck parking facilities in the state of Tennessee.

The research also developed one desktop and two web-based tools (accessible from <https://sites.google.com/view/res2019-16/home>) that allows Tennessee Department of Transportation (TDOT) engineers and planners to perform additional data analysis, apply the methodology developed in this research, and develop presentation material that can be used to inform the public and decision makers. The tools developed allow for the

estimation of multiple rest area performance measures including volume to capacity ratios, parking duration and violation rates by time of day, day of week and season. The data, available through these tools, are of the base year 2018 (year the GPS truck data was available) and of projections for 2025, 2030 and 2035 assuming a 4 percent truck demand annual increase.

Results from a combination of data analytics using truck GPS and count data, and a survey of the trucking industry, identified fifteen existing rest areas that would require capacity upgrades, and two segments of the interstate network (I-40 between Jackson and Nashville and I-75 north of Knoxville) that lack adequate truck parking capacity by 2035 and could benefit from construction of new rest areas. Results of the data analysis and survey also revealed that one a main issue with truck parking in Tennessee is the lack of preparation from the truckers and recommends that TDOT invests in technology to provide real time information on truck parking availability. The research team recommends that a larger study covering multiple neighboring states (AR, MS, AL KY, GA) and a longer time period of GPS data is performed to obtain more robust and reliable results and identify collaboration opportunities between the states. It is also recommended that further research is performed to include accident analysis (involving trucks or during presence of illegal parking), freight facility locations, commodity flows (disaggregate at zip code level), and trip types (long haul, short haul, drayage etc.). Such a study would be a major undertaking but the benefits for the State DOTs involved and the trucking industry would be significant.

Table of Contents

Executive Summary	iv
Table of Contents	vi
List of Tables	vii
List of Figures	viii
1. Introduction	1
1.1 <i>Definitions</i>	2
1.2 <i>Organization of Report</i>	2
2. Literature Review	3
3. Survey	8
4. Data Collection and Process	15
4.1 <i>Data Set Description</i>	15
5. Expansion Factors, Truck Parking Utilization and Violations	17
5.1 <i>Expansion Factors</i>	17
5.2 <i>Truck Parking Utilization and Violation Rates Methodology</i>	17
5.3 <i>Truck Parking Utilization and Violation Rates Results</i>	18
6. New Truck Rest Areas and Expansion of Existing Facilities	32
6.1 <i>Existing Truck Rest Areas Capacity Expansion</i>	33
6.2 <i>New Truck Rest Area Locations</i>	36
6.3 <i>Additional Consideration/Recommendations</i>	41
7. Conclusions	41
8. REFERENCES	43
9. APPENDIX A: SURVEY INSTRUMENT	45

List of Tables

TABLE 4-1 GPS DATA SUMMARY..... 15
TABLE 6-1 CANDIDATE PUBLIC REST AREAS FOR EXPANSION BASED ON 2035 PROJECTIONS 35
TABLE 6-2 LOCATIONS FOR NEW FACILITIES (LOCATION WHERE A REST AREA EXISTS IN ONLY ONE
DIRECTION)..... 35

List of Figures

FIGURE 3-1 PARTICIPANTS' AGE GROUPS	9
FIGURE 3-2 PARTICIPANTS' GENDER	10
FIGURE 3-3 PARTICIPANTS' EMPLOYMENT STATUS.....	10
FIGURE 3-4 FREQUENCY OF PARKING IN TENNESSEE.....	11
FIGURE 3-5 HOW TRUCK DRIVERS PLAN TO FIND PARKING	11
FIGURE 3-6 WHICH TRUCK PARKING APPLICATION DO TRUCK DRIVERS USE.....	12
FIGURE 3-7 HOW FAR IN ADVANCE DO TRUCK DRIVERS PLAN THEIR PARKING LOCATION	12
FIGURE 3-8 HOW LONG DOES IT TAKE TO FIND TRUCK PARKING IN TENNESSEE?	13
FIGURE 3-9 HOW OFTEN DO YOU EXPERIENCE THE FOLLOWING IN TENNESSEE? (PART B).....	14
FIGURE 3-10 INDICATE HOW EASY IT IS TO FIND TRUCK PARKING IN TENNESSEE IN THE FOLLOWING SCENARIOS.....	14
FIGURE 4-1 PUBLIC AND PRIVATE TRUCK REST AREAS IN TENNESSEE	16
FIGURE 4-2 REST AREA SPATIAL POLYGON WITH SAMPLE GPS DATA EXAMPLE	16
FIGURE 5-1 MAXIMUM NUMBER OF TRUCKS BY HOUR AND LOCATION (PUBLIC REST AREAS).....	20
FIGURE 5-2 AVERAGE NUMBER OF TRUCKS BY HOUR AND LOCATION (PUBLIC REST AREAS).....	20
FIGURE 5-3 MAXIMUM UTILIZATION BY HOUR AND LOCATION (PUBLIC REST AREAS).....	21
FIGURE 5-4 AVERAGE UTILIZATION BY HOUR AND LOCATION (PUBLIC REST AREAS).....	21
FIGURE 5-5 MAXIMUM NUMBER OF TRUCKS BY HOUR AND MONTH (PRIVATE REST AREAS)	22
FIGURE 5-6 AVERAGE NUMBER OF TRUCKS BY HOUR AND MONTH (PRIVATE REST AREAS)	22
FIGURE 5-7 MAXIMUM UTILIZATION BY HOUR AND MONTH (PRIVATE REST AREAS)	23
FIGURE 5-8 AVERAGE UTILIZATION BY HOUR AND MONTH (PRIVATE REST AREAS)	23
FIGURE 5-9 MAXIMUM NUMBER OF TRUCKS BY HOUR AND MONTH (ALL RAMPS IN TENNESSEE) ...	24
FIGURE 5-10 MAXIMUM PARKING DURATION BY START HOUR AND LOCATION (PUBLIC REST AREAS)	24
FIGURE 5-11 AVERAGE PARKING DURATION BY START HOUR AND LOCATION (PUBLIC REST AREAS)	25
FIGURE 5-12 MAXIMUM PARKING DURATION BY START HOUR AND MONTH (PRIVATE REST AREAS)	25
FIGURE 5-13 AVERAGE PARKING DURATION BY START HOUR AND MONTH (PRIVATE REST AREAS)	26
FIGURE 5-14 MAXIMUM PARKING DURATION BY START HOUR AND MONTH (ALL RAMPS IN TENNESSEE).....	26
FIGURE 5-15 AVERAGE PARKING DURATION BY START HOUR AND MONTH (ALL RAMPS IN TENNESSEE).....	27
FIGURE 5-16 MAXIMUM PARKING VIOLATIONS BY MONTH (PUBLIC REST AREAS).....	28
FIGURE 5-17 AVERAGE PARKING VIOLATIONS BY MONTH (PUBLIC REST AREAS).....	29
FIGURE 5-18 MAXIMUM PARKING VIOLATIONS BY TOD (PUBLIC REST AREAS)	30
FIGURE 5-19 AVERAGE PARKING VIOLATIONS BY TOD (PUBLIC REST AREAS).....	31
FIGURE 6-1 WEB-BASED TOOL FOR CAPACITY EXPANSION AND PARKING VIOLATION ANALYSIS	34
FIGURE 6-2 TENNESSEE INTERSTATE NETWORK	37
FIGURE 6-3 MEDIAN UTILIZATION (2035 PROJECTION – 4% ANNUAL INCREASE RATE) LESS THAN 60% WITH 20-MILE BUFFER, INTERSTATE NETWORK OVERLAP	38
FIGURE 6-4 MEDIAN UTILIZATION (2035 PROJECTION – 4% ANNUAL INCREASE RATE) LESS THAN 70% WITH 20-MILE BUFFER, INTERSTATE NETWORK OVERLAP	39
FIGURE 6-5 MEDIAN UTILIZATION (2035 PROJECTION – 4% ANNUAL INCREASE RATE) LESS THAN 80% WITH 20-MILE BUFFER, INTERSTATE NETWORK OVERLAP	40

1. Introduction

The freight transportation system in the United States (U.S.) has one of the most valuable contributions to the nation's economy and growth. Within the freight system, truck traffic is expected to increase by 45 percent by 2040. At the present time, trucks move more than 70 percent of all freight by tonnage and 79.8 percent by value (www.trucking.org/article/ATA-American-Trucking-Trends-2017). Long-term economic growth, as well as our nation's dramatic shift to e-commerce, is expected to result in even greater demand for truck transportation. Whether needed for staging, pick-ups and deliveries, or hours-of-service compliance, truck parking is a critical component of supply chain operations. However, in nearly every state in the US there is a gap between the demand and supply of truck parking facilities (mainly during the peak hour periods than can vary from location to location e.g., location in the vicinity of intermodal facilities and on interstates). Other factors that hinder truck parking include limited road networks, municipal truck parking restrictions, and declining infrastructure investments; all of which put considerable constraints on a truck driver's ability to deliver goods safely, reliably, cost-effectively, legally, and on-time. When truck parking is inadequate, truck drivers are often forced to park in unauthorized or dangerous locations, creating new hazards for both the truck driver and public. When this happens, truck drivers may be ticketed by enforcement or sent down the road fatigued and in violation of federal law. Moreover, truck parking has been indicated as the most influential factor for route selection decisions.

According to the Federal Motor Carrier Safety Administration (FMCSA), truck drivers can be on duty for 14 hours, of which they can drive for 11 hours. After driving for 11 hours, drivers must have some combination of 10 hours of rest until they can drive again. Furthermore, the current FMCSA hours of service rule require truck drivers to take a 30-minute break only after 8 hours driving without a 30-minute break. As noted, there is a negative economic impact to the truck parking shortage. Recent research by The American Transportation Research Institute (ATRI) documents that truck drivers now need to sacrifice revenue drive-time to commence looking for truck parking, which could exacerbate both the truck driver shortage and entice drivers to later speed to make up for lost wages.

Truck parking availability is a challenging problem associated with routing, delivery requirements and accommodating rest periods. The objectives of this research are to provide the Tennessee Department of Transportation (TDOT) with guidance on truck parking issues and opportunities, by identifying parking needs (i.e., addition of capacity and/or construction of new facilities); developing truck parking violation rates (i.e., truck parking at on- and off-ramps) and developing and applying a methodology to identify candidate locations for new truck parking facilities in the state of Tennessee. This study extends the work done by Golias et al. (2017) and Cherry et al. (2017) who used truck

Global Positioning System (GPS), direct observation, and survey data to evaluate the performance of truck parking in the state.

1.1 Definitions

Many terms are used within the truck parking topic. For the remainder of this report the following definitions are used:

- **Rest area:** Public or private facility with specific design for truck parking and amenities for the drivers.
- **Capacity:** Number of authorized truck parking spaces in a specific rest area.
- **Parking Demand:** Number of trucks parked at a specific rest area per time unit (e.g., hour or day).
- **Utilization:** Percentage of trucks parked in a specific parking space at a rest area for a predefined period (e.g., hour, day).
- **Duration:** Time period a truck occupies a specific parking space at a rest area.
- **Peak Hours:** Hours in a day that rest areas exhibit the highest utilization rates.
- **Violation:** A truck is parked in a non-designated area (e.g., entrance lane (on-ramp) or exit lane (off-ramp) of a highway interchange).
- **Expansion or Expansion Factor:** Multiplier to convert sample of GPS data into the actual population.

1.2 Organization of Report

The remainder of the report is structured as follows. Chapter 2 provides a brief overview of existing literature relevant to the scope of the project. Chapter 3 presents and discusses the findings from a survey of the trucking industry. Chapter 4 describes the datasets used in this study. Chapter 5 is dedicated to the expansion factor, utilization rates, and truck parking violation rates estimation. In Chapter 6, the methodology for determining existing rest areas capacity expansion needs and identifying candidate locations for new rest areas is presented along with the results of the application of the methodology in Tennessee. Finally, in Chapter 7, conclusions, recommendations, and future research opportunities are discussed.

2. Literature Review

In this section, the relevant literature on truck parking utilization rates, violations, and models developed to identify candidate locations for new rest areas is summarized. Lack of available truck parking has become a serious concern for truck drivers, motor carriers, truck facility operators and public. Seeking to comply with the Hours of Service (HOS) rules, truck drivers may be forced to park in undesignated and, in many scenarios, unsafe locations. While truck parking appears to only be ranked as the fifth (5th) critical issue among all industry stakeholders, based on a recent report, “Critical Issues in the Trucking Industry” (ATRI, 2018) (1), the truck parking issue ranked 2nd overall among truck drivers for two consecutive years. To improve truck parking in strategic locations many state-level studies have been conducted.

In 2017, the North Carolina’s Department of Transportation evaluated the optimal way to invest public and private sector transportation resources targeted for truck parking. The study identified real-time technologies for monitoring parking utilization and estimated the financial requirements for converting existing rest areas, weigh stations and other properties to truck parking, among other outcomes (2). Other well recognized truck parking initiatives include the North Central Texas Council of Governments (3) and the Virginia Department of Transportation (4), both of which evaluated the frequency of truck parking along interchange ramps, rest areas, and welcome centers along key freight corridors to determine where additional temporary and overnight truck parking is needed. The North Jersey Transportation Planning Authority (NJTPA), in two different reports in 2008 (5) and 2009 (6), researched a series of truck parking issues and strategies including development of an inventory of truck parking facilities, truck parking demand models, and parking adequacy ranking based on a 2002 Federal Highway Administration (FHWA) methodology. One of the key findings of these reports was that the truck parking demand is skewed toward overnight periods and, as demand increases, truck drivers must cease revenue trips earlier in the day to ensure that parking spaces are available. The result is that many truck parking facilities are now filled beyond capacity by early evening hours. A Mid-America Freight Coalition (MAFC) study in 2017 (7) concluded that in most large metro areas there are affordable and accessible parcels that could be utilized for truck parking; for instance, developing truck parking facilities near city centers, or in close proximity to freight generators, could benefit both truck parking and on-time delivery. Criteria used by the Miami-Cade MPO (8) for evaluating candidate locations for truck parking included neighborhood impacts, distance to freeways, site visibility from freeway, freeway truck percentages, facility accessibility, future truck volumes, and cost.

In 2015, the Kansas Department of Transportation (KDOT) in association with Kansas Turnpike Authority (KTA) evaluated factors that can affect truck parking decision-making such as physical obstructions and barriers, regulations, and parking policies (9). The FHWA conducted an activity report in 2016, in which they suggested solutions to parking

capacity, technology and data supporting truck parking, transportation funding and new policies and programs that state, regional and local governments should consider to address the truck parking problem (10). Also, to help drivers make informed parking-related decisions, eight states within the Mid America Association of State Transportation Officials (MAASTO) region have developed a regional Truck Parking Information Management System (TPIMS) (11). The FHWA in 2002 released a comprehensive study (12) which described a methodology that can be applied where shortages in truck parking exist. This methodology contained four steps: 1) estimates of parking demand over roadway segments were developed using a modeling approach; 2) estimates of parking supply were gathered for each segment using available data sources; 3) a summary of the supply and demand for each roadway segment was provided to partners for review, verification, and comment; and 4) a final calibration of the model was completed, and the calibrated model was used to evaluate shortages. Srivastava et al. (2012) (13) used location clustering and cluster ranking to identify the areas, in which truck parking shortages have been experienced by truckers and to determine which areas required immediate relief. The analysis included a discrete ranking process that considered frequency and severity for prioritizing locations regarding investment in improving parking. Among several alternative methods, the nearest neighbor hierarchical clustering was found to be the most appropriate. Clusters generated by this process were then ranked in order to decide the priority for capacity expansion.

As previously mentioned, parking demand estimation or prediction along major freight corridors is essential when addressing truck parking issues. Over the years, various models and tools have been developed to tackle different aspects of truck parking. According to Gingerich, Maoh, and Anderson (2015) (14) obtaining freight data for route choice modeling is difficult, and most of the existing studies rely on surveys.

FHWA developed a methodology to predict parking demand using peak daily truck volumes, average truck travel time, and short-haul and long-haul truck-hours of travel. (15). Garber et al. (16) in a study on I-81 in Virginia introduced the number and percentage of trucks in the traffic stream, the distance from the interstate to the truck stop, and the amenities provided at truck stops as main factors that can affect the demand for commercial heavy truck parking. Garber (17) in another research study, prepared for the Virginia Transportation Research Council, in order to analyze deficiency and truck parking demand estimation, assumed that the future demand was the total of the maximum accumulation for the year obtained from their model, the predicted illegal parking, and the predicted legal parking at the rest areas. The Ohio Department of Transportation developed a LOTUS 1-2-3 spreadsheet (micro-level model) that utilized the variation in traffic volume with time and parking demand duration distribution tables to develop a daily accumulation of trucks for a given rest area (18). The spreadsheet could use three traffic levels: one-way ADT, one-way ADT with overall percentage of trucks, and one-way volume of total traffic with volume of trucks from each 24 one-hour periods. The results

produced by the spreadsheet were similar to those obtained from observations. The Transportation and Mobility Planning Division of the Virginia Department of Transportation (VDOT) (17) updated a macroscopic corridor-level parking demand model, originally developed by the Minnesota Department of Transportation. The model was later recommended by the American Association of State and Transportation Officials (AASHTO) for use in estimating required truck parking spaces in developing statewide rest areas. Later, the Minnesota Department of Transportation in collaboration with the Virginia Department of Transportation updated that model in order to take under consideration the impact of non-traffic factors such as location, food facilities, lighting, and parking spaces available at nearby truck stops, which were previously not included. Haque et al. (2017) (19) developed econometric models using GPS data to predict truck parking utilization at rest areas to improve truck parking management. They also developed generalized ordered response probit (GORP) models to identify the factors which have affected the truck parking utilization. Regression models have also been used to estimate and predict truck parking on interstates (Golias et al. 2012) (20). Factors, such as percentage of trucks, total truck volume, distance to nearest truck stop, parking duration, etc., have been used to develop models able to estimate future demand. The results showed that excess demand will continue to increase unless truck parking capacity is expanded, or new facilities are built.

Identifying candidate locations for truck parking could be a proven vital solution to increase supply and satisfy the increasing demand. The Atlanta Regional Commission in 2018 used GPS data for analyzing truck parking and the FHWA in 2002, developed a truck parking supply and demand model for the base year of 2012 and future year of 2045 for both public and private parking. They also used truck GPS data to assess the truck parking utilization in different corridors across the region (21). Also, ATRI in its second Technical Memo reported in 2017 (22) used GPS data collected from Minnesota trucks to evaluate truck parking supply and demand through a GIS analysis. In this scenario study, the researchers estimated the total number of trucks in each location, by applying an expansion factor that expanded their GPS sample to represent 100 percent of trucks at rest area counts in hourly bin counts. The data analysis provides guidance on where truck parking investments are most needed based on utilization of existing truck parking facilities. Another way to identify candidate locations near major transportation corridors is using the FISHF Model (Marlin Engineering, Inc. (2010) (23) to estimate demand for short-haul and long-haul trips. The Center for Advanced Infrastructure and Transportation (CAIT) (24) at Rutgers University did this through the creation of a comprehensive cost-benefit analysis (CBA) based methodological framework, which attempted to evaluate current truck parking and identify criteria which are effective at the local and site levels for potential locations to develop or expand truck parking in New Jersey. The demand analysis was conducted in three steps: first, truck volumes per day were calculated; second, the parking inventory of public rest areas and private truck stops for this segment were obtained; and in the final step, the truck parking demand estimation formulas were

applied to estimate the parking demand for each analysis segment.

Count and survey data have been used to determine and predict truck parking demand and supply characteristics. Surveys of truck drivers and truck stop owners have been proved useful to generate statistics associated with the truck parking situation in several states (16); (25). Anderson et al. (26) collected data through a truck driver survey in the Pacific Northwest, regarding their experiences related to the availability of safe and adequate parking. The research then utilized a binary model to evaluate how different factors can impact the likelihood of finding safe and adequate parking from the perspective of the driver. In their model, only 11 of the 134 indicator variables documented, were found statistically significant that could affect the probability that a driver will experience issues finding safe and adequate parking. The research results illustrated that drivers of less-than-truckload (LTL) shipments, weekend shipments, and older drivers have significantly fewer challenges finding appropriate parking. ATRI, in its first Memo related to Managing Critical Truck Parking (27), prepared and presented driver surveys online and at the Mid-America Trucking Show (MATS). More than 1400 survey responses were analyzed on questions of a variety of truck parking issues, including who should be responsible for truck parking fees and what is the business model for “reservation-for-free” systems.

Adams et al. (28) systematically examined truck parking issues and recommended low cost solutions. The researchers also developed a GIS online survey instrument to collect information from remote participants. Therefore, the survey was conducted continuously throughout the study period via the internet. The study concluded that fatigued truck drivers are unable to find parking due to HOS regulations; therefore, increasing parking demand at night and exacerbating congested parking facilities. The Washington Department of Transportation (29) sought a better understanding of the lack of truck parking across the state and prepared another report in 2016 which focused on online surveys, roundtable discussions, and one-on-one interviews to identify issues related to truck parking. The report analyzed data to identify key corridors and locations with the largest number of truck parking capacity issues and identified locations for expanding parking at key locations. FHWA (30) assessed truck parking needs and preferences, by conducting a survey to determine how truck drivers plan for and address their parking needs; how truck drivers select when, where, and at which facilities they park; and what truck drivers think of the adequacy of current parking facilities. More than 2,000 truck drivers from all over the United States and Canada participated in the survey, and responses were collected from both long-haul and short-haul drivers at private truck stops through site visits and mail-out distributions. In 2016, ATRI (31), to address the truck parking shortage, concluded a study of 325 truck drivers, who completed a diary representing a total of 2035 days of truck parking activity and 4763 unique stops. From the data collected, a table displaying driver estimates of miles driven by region was established. Drivers were also asked for any additional thoughts they have on parking-

related issues including desired amenities, parking purposes, and desired improvements. Girom-Valderama et al. (32) conducted a survey about safe truck parking on Pactrans interstate corridors. Data was collected, and results revealed the main reason for parking at a truck stop is to wait to meet a specific delivery window or locating another load to pick up.

Truck parking shortages lead truck drivers to either keep driving without rest, which increases the risk of accidents or park at undesignated areas, such as the shoulders along the on- and off-ramps of rest areas and other interchange ramps (33). Chatterjee et al. conducted an extensive survey of truck volumes and utilization at all public rest areas in Tennessee to understand the usage characteristics of truck parking in public rest areas at night and to assess the nature and magnitude of the problem (34). Recently, the Texas Department of Transportation published a study that includes truck parking utilization analysis for the State of Texas and a methodology to identify locations for new rest areas based on parking demand, truck related collision patterns, and freight significance (35). To understand and ensure proper utilization of truck parking at rest areas at specific periods of time, research is needed to understand utilization during different time periods and the factors associated with this utilization. Furthermore, research is needed to understand and quantify parking violations (e.g., parking on on- and off- ramps). At the same time, develop a methodology that would assist decision makers in identifying locations for new or expanded truck parking locations. Truck parking adequacy is a real, multi-challenging problem associated with routing, delivery requirements, and accommodating rest periods.

3. Survey

This section presents the results from a survey conducted by the research team to support the goals and objectives of the project. The main purpose for conducting this survey was to gather information on truck parking from the trucking industry professionals on their level of satisfaction of truck rest areas (public and private) and on their experience, as well as, their input on possible improvements or current drawbacks of available truck parking supply. The survey instrument is available in Appendix A on page 33. 481 drivers participated in the survey, with 311 of them completing it in its entirety. For the survey analysis, only completed responses were taken into consideration. Figures 3-1 to 3-12 present a summary of the survey responses (also available through the online tool accessed from here: <https://sites.google.com/view/res2019-16/home>).

Some general observations and patterns identified are as follows:

- Over 60 percent were over the age of 45 (Figure 3-1), 80 percent were male, and 10 percent preferred not to answer (Figure 3-2).
- More than half of the participating drivers are employee drivers (Figure 3-3).
- More than 30 percent of the participants look for available parking in Tennessee 2 to 4 times a week (Figure 3-4).
- Almost half of the participants do not plan a time for selecting/finding a parking location. They prefer instead to find the nearest parking within the HOS limit and drive until they find parking (Figure 3-5).
- The most used truck parking application by the drivers is Trucker Path (Figure 3-6) with 50 percent of those responding “Other” not using any application.
- Only 17 percent plan their parking location before their shift starts (Figure 3-7).
- Almost half of the participants spend between 30 minutes and 1 hour to find parking (Figure 3-8)-Note that this time is used in section 6.
- It is almost equally difficult to find parking in both public and private rest areas. A very alarming and troubling response is that almost 51 percent of participants reported that they occasionally and/or often park in unsafe locations (Figure 3-9).
- Shippers/receivers in Tennessee rarely allow on-site parking outside of appointment hours while (un)loading delays often exceed 1 hour (Figure 3-9).
- Almost 40 percent of the participants change their route selection due to parking challenges in Tennessee (Figure 3-9).
- 50 percent of the participants strongly disagree or disagree that truck parking supply in Tennessee can satisfy the mandatory HOS breaks (Figure 3-10).
- Around 30 percent of participants indicated that it is difficult to find parking while waiting to make a scheduled delivery (Figure 3-10) although this is not a problem that should concern TDOT but rather the individual municipalities, cities, and MPOs.
- Compared to neighboring states, parking capacity in Tennessee does not seem to

be performing any better or worse with the majority (55 percent) of participants being neutral, or agreeing/strongly agreeing that Tennessee is as easy to find parking, and with only 37 percent strongly disagreeing/disagreeing.

Responses from the survey do not match the results from the data analysis that showed that truck parking capacity is available in Tennessee within 30 to 60 minutes of driving from any location on the interstate system. In addition, responses to the survey questions seem to contradict each other. For example, even though participants indicated that they can find parking within 30 to 60 minutes of their HOS break, only 24 percent responded that they can find parking to meet HOS break requirement. It may be the case that investment in information technology to assist truckers better plan for their parking needs would have a higher return on investment than capital spending for new parking facilities.

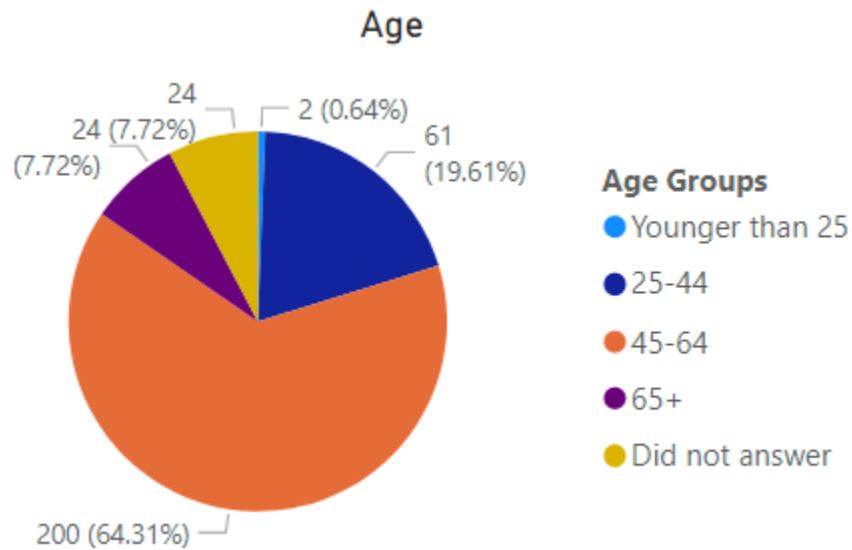


Figure 3-1 Participants' age groups

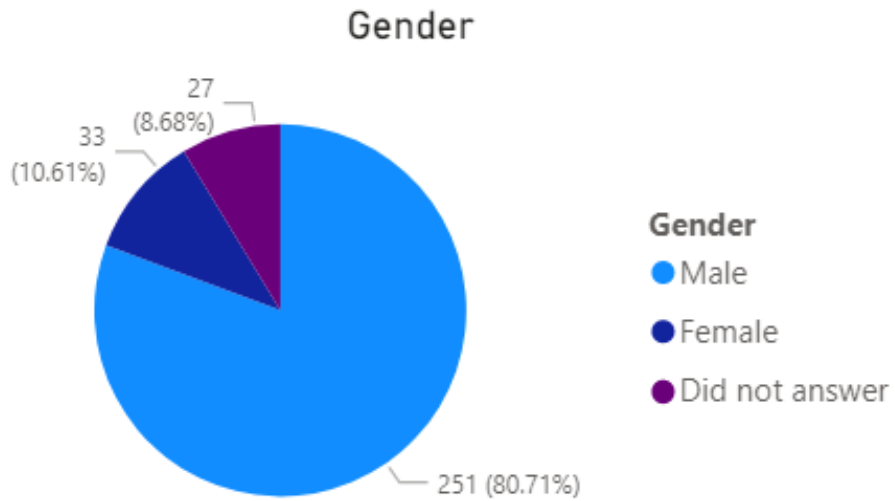


Figure 3-2 Participants' gender

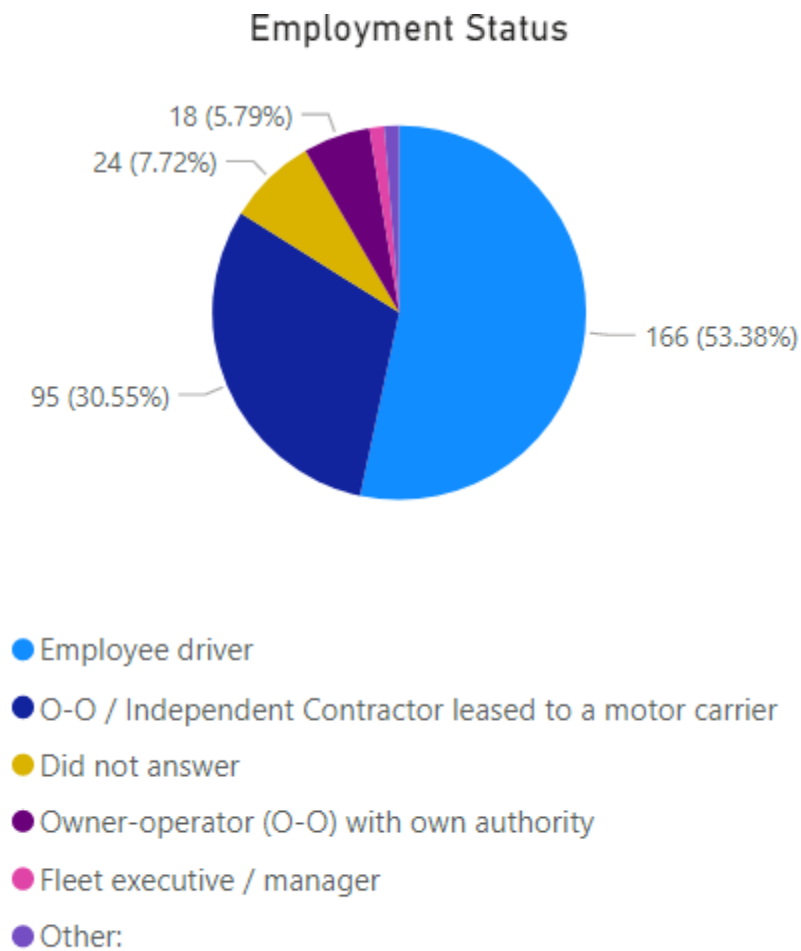


Figure 3-3 Participants' employment status

How often truck drivers need parking in Tennessee?

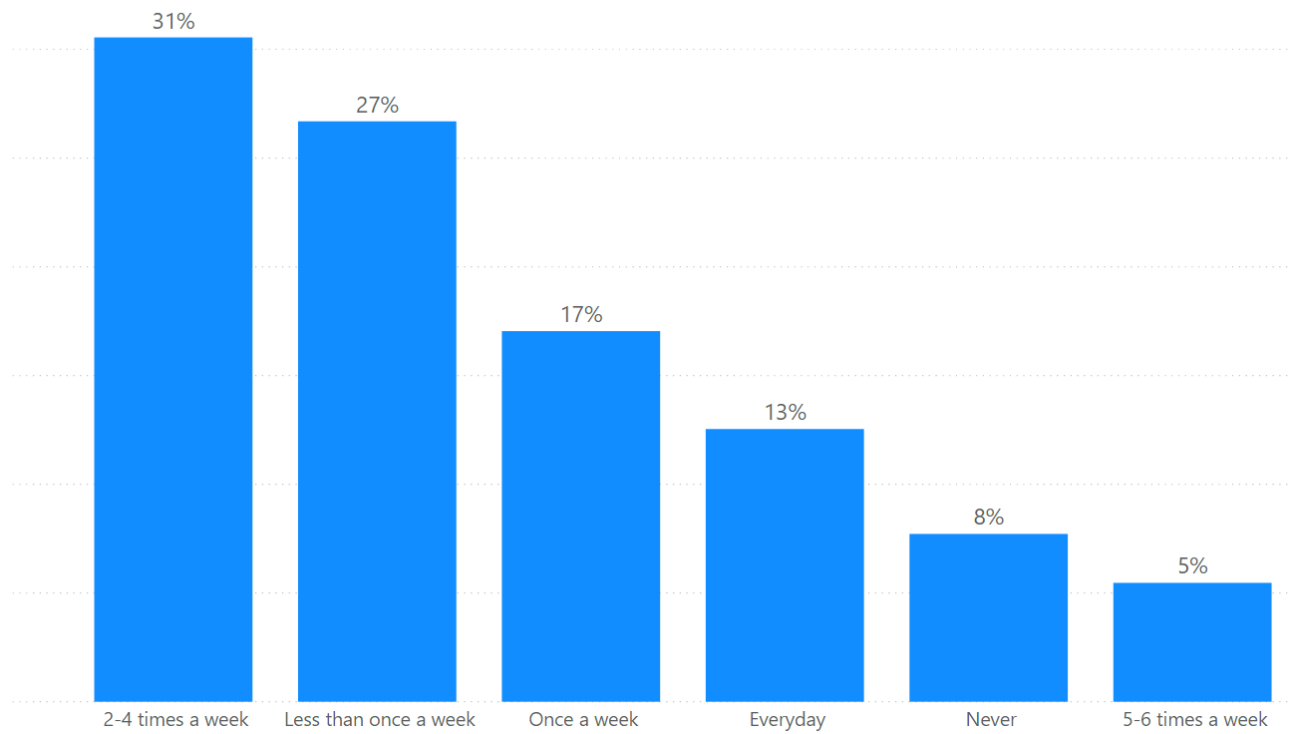


Figure 3-4 Frequency of parking in Tennessee

How truck drivers find parking

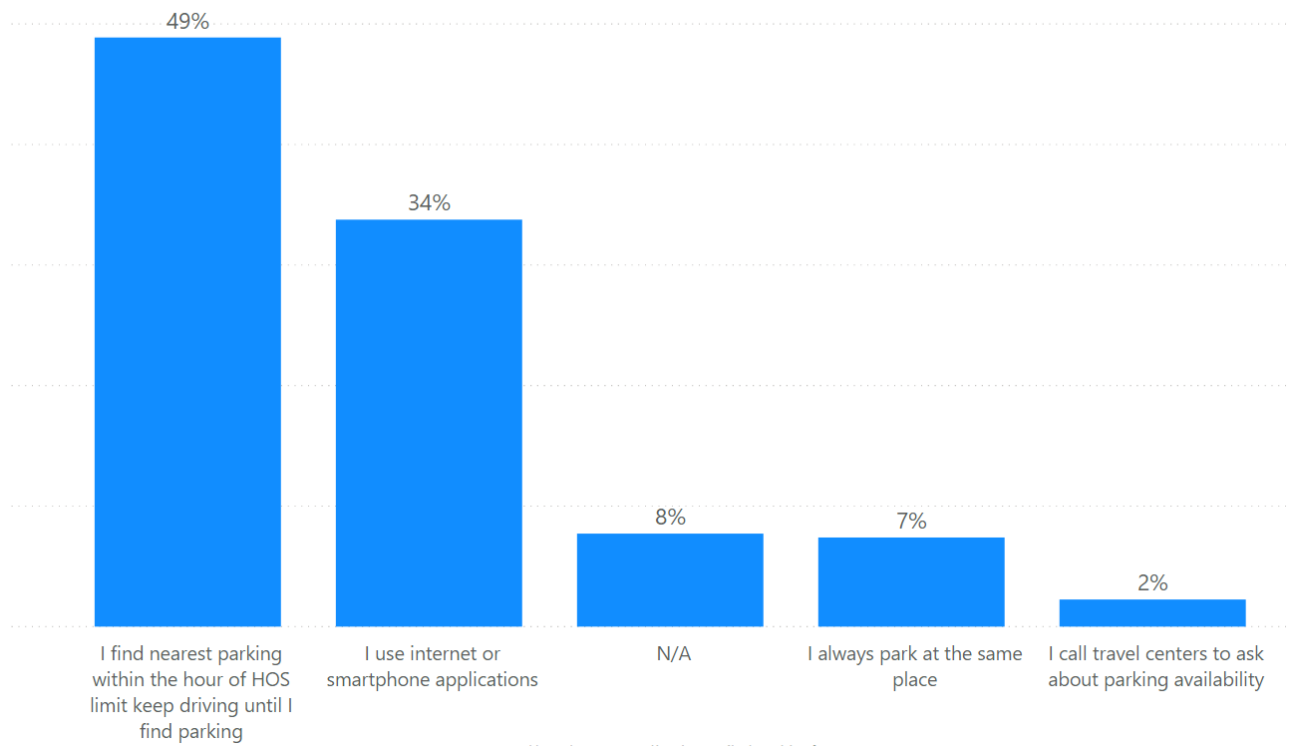


Figure 3-5 How truck drivers plan to find parking

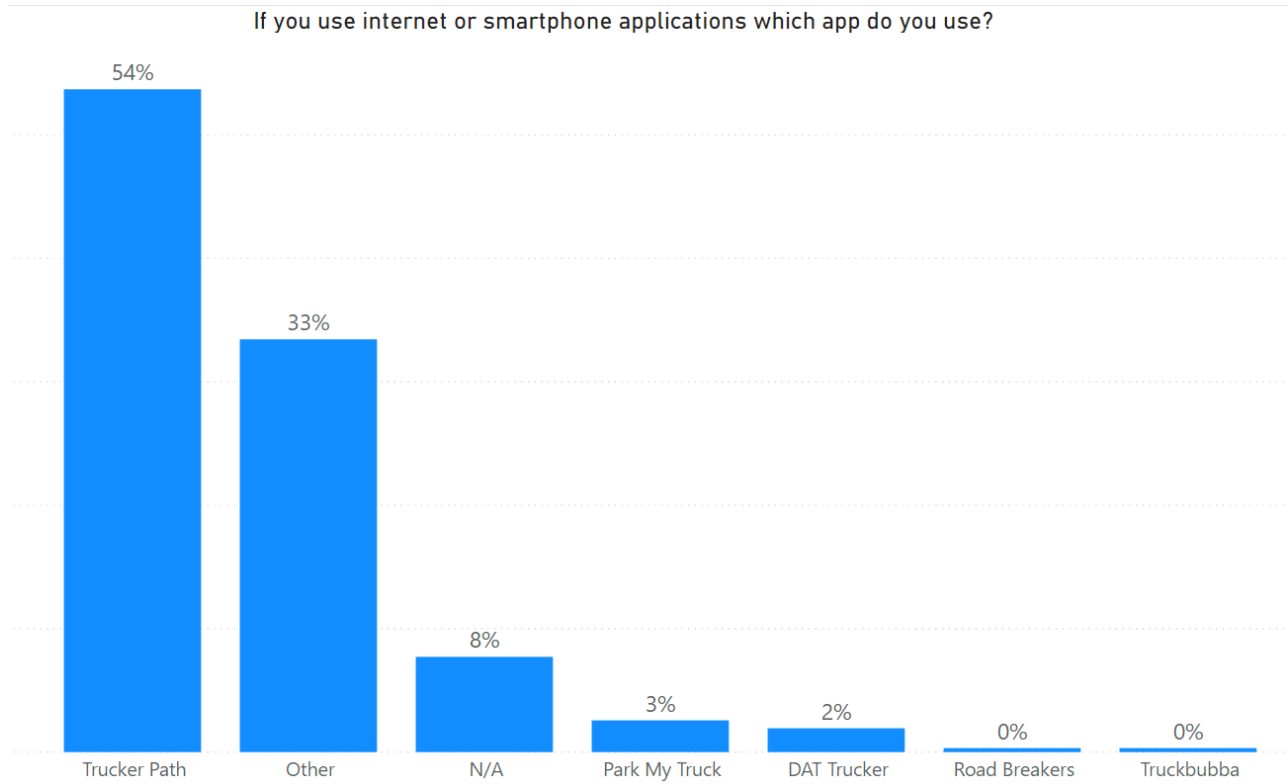


Figure 3-6 Which truck parking application do truck drivers use

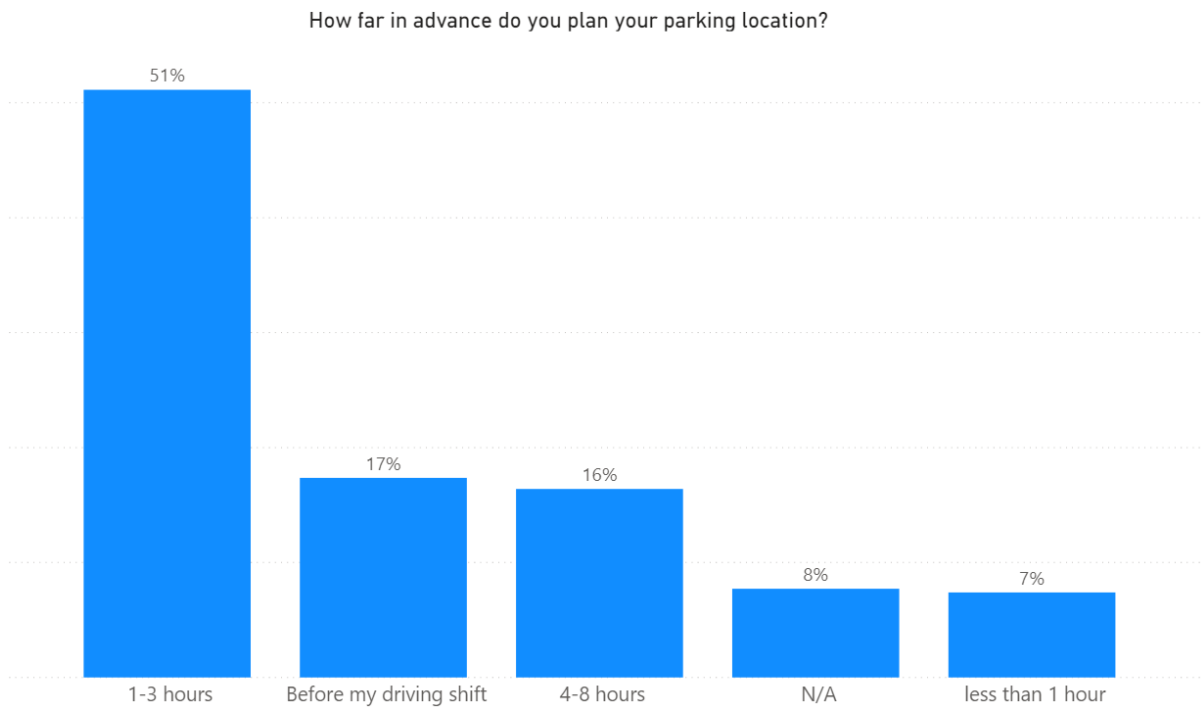


Figure 3-7 How far in advance do truck drivers plan their parking location

On average, how long does it take you to find truck parking in TN?

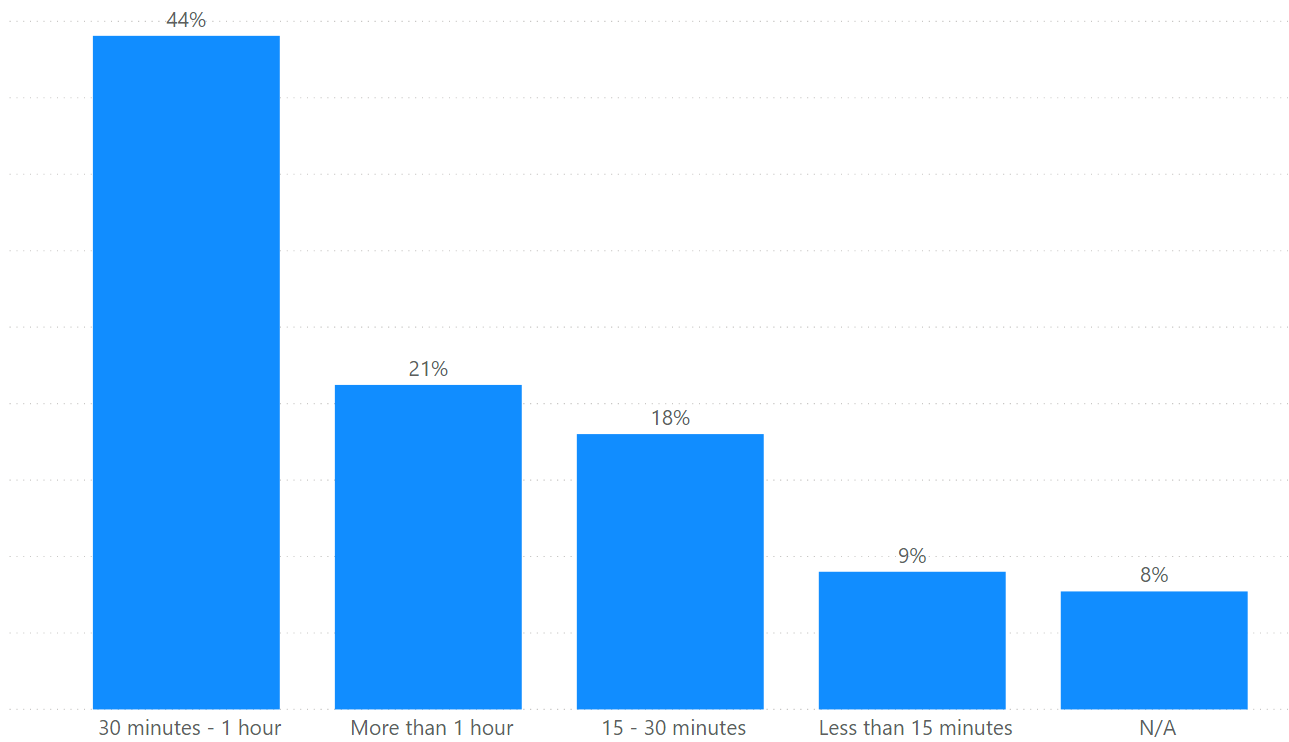


Figure 3-8 How long does it take to find truck parking in Tennessee?

How often do you experience the following in Tennessee?

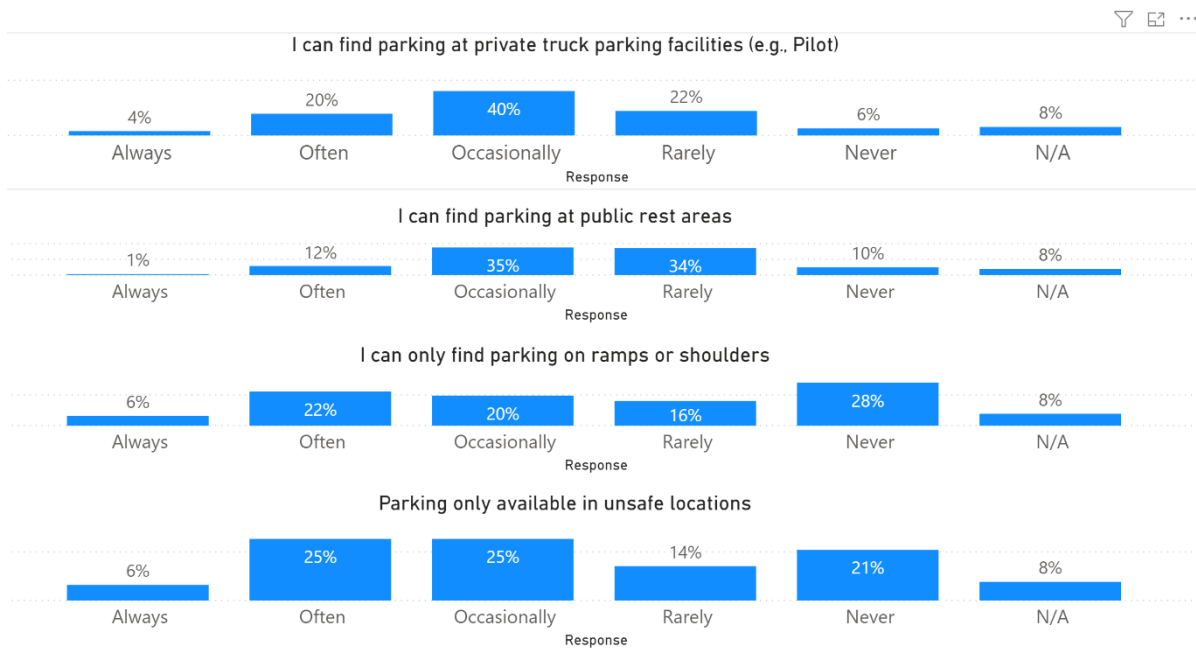


Figure 3-9 How often do you experience the following in Tennessee? (Part A)

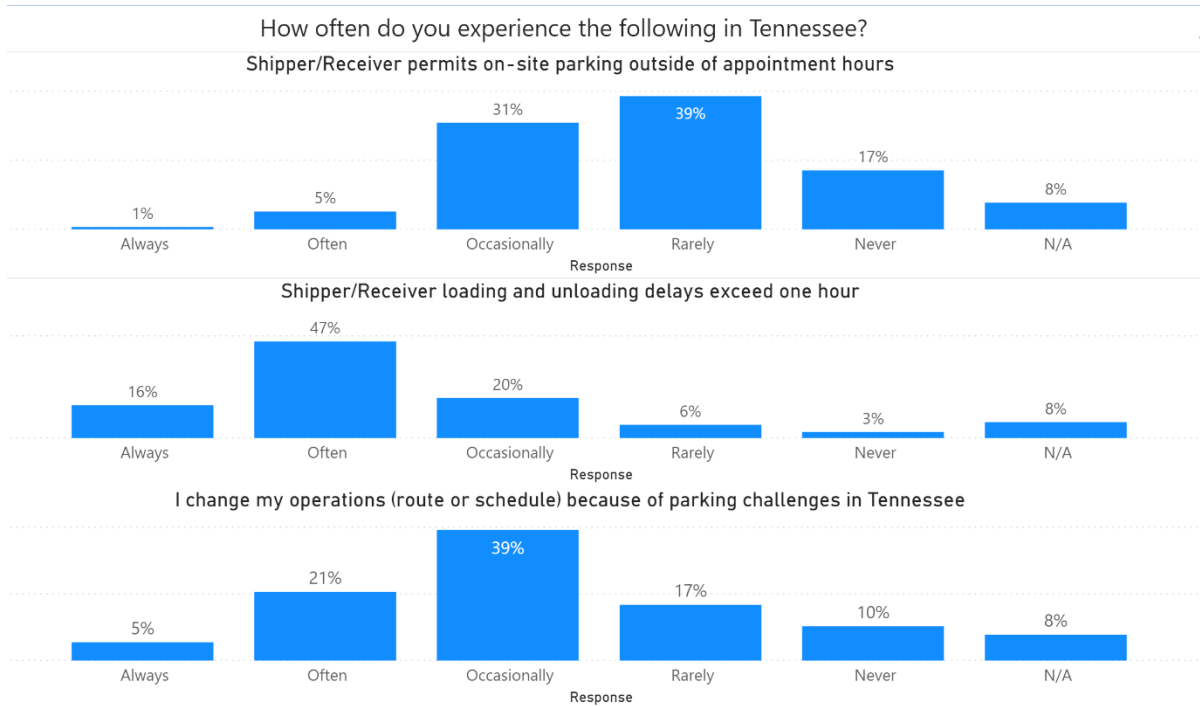


Figure 3-9 How often do you experience the following in Tennessee? (Part B)

Please indicate how easy it is to find truck parking in Tennessee with the following scenarios.
 It is easy to find truck parking in Tennessee in comparison to the surrounding states (North Carolina, Georgia, Alabama, Mississippi, Arkansas, Missouri, Kentucky and Virginia)

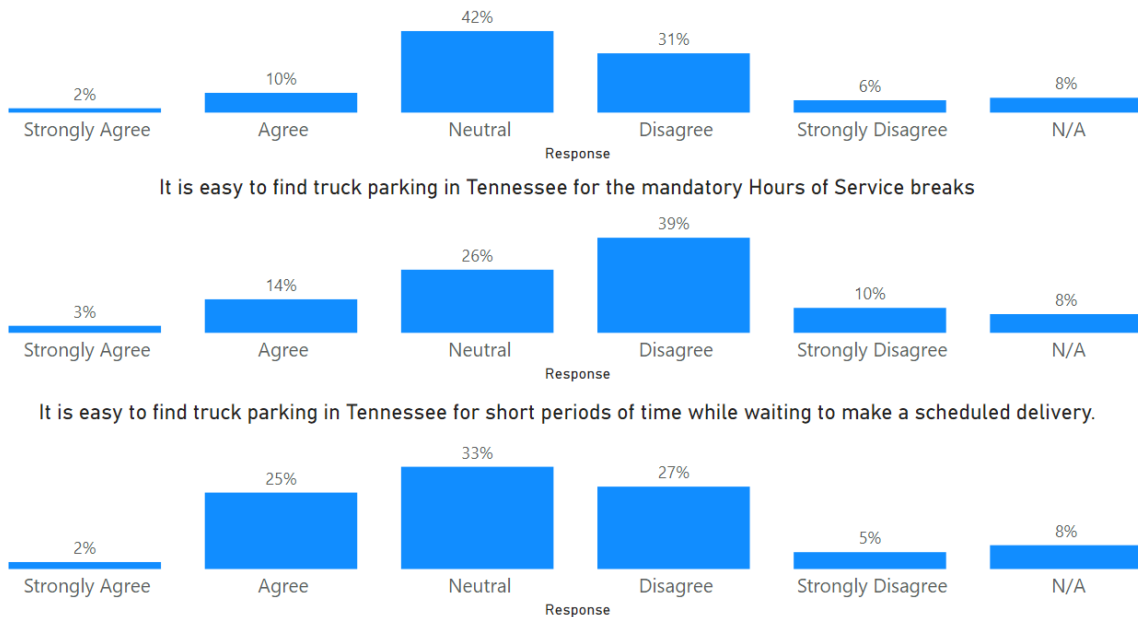


Figure 3-10 Indicate how easy it is to find truck parking in Tennessee in the following scenarios.

4. Data Collection and Process

In this section, we briefly discuss the data used in this project. These datasets included observed and/or estimated truck flows (either from GPS, truck counts, and the Enhanced Tennessee Roadway Information Management System (ETRIMS) database), a detailed roadway network, and the locations of the public and private truck parking facilities in Tennessee. Next, we provide a brief description and descriptive statistics of the available datasets used in this project.

4.1 Data Set Description

ATRI truck GPS data: ATRI provided the University of Memphis team with aggregated and anonymized truck GPS data with speed less or equal 25 mph for the first two weeks of March, May, and October 2018 and the last two weeks of July 2018. In order to assess trucks that are parked or in the process of finding truck parking, ATRI limited the data to trucks at or below 25 MPH; this eliminates a substantial amount of GPS data “noise” – by ensuring that the trucks are indeed involved in truck parking activities. Additionally, ATRI provided aggregated and anonymized truck GPS data for the first two weeks of October with no speed limitations to be used in the estimation of the expansion factors. For each GPS point, the set contains the truck ID, a timestamp (without time zone), the longitude and latitude, and instantaneous vehicle speed. To prepare the data to be used in the remaining tasks, timestamp was adjusted to local Tennessee time zones. A summary of the data received is shown in table 4-1.

Table 4-1 GPS Data Summary

Year 2018 Month	# of pings (in millions)	# of unique trucks	% of unique trucks in dataset
March	~123.6	~152K	~0.12%
May	~124.6	~146K	~0.12%
July	~133.5	~145K	~0.11%
October	~113.7	~136K	~0.12%
October No Speed Limit	~171.4	~140K	~0.08%

ETRIMS network with AADT: This dataset was acquired from the ETRIMS website. It contains the Tennessee road network and AADT (Average Annual Daily Traffic) with truck percentages for 2018.

Hourly truck volumes: This data set was provided by TDOT and contained hourly and daily truck volumes from truck count stations in Tennessee.

Public and Private rest areas: A total of 47 public and 112 private rest areas were identified in Tennessee (Figure 4-1). For the public rest areas three types of polygons were created to capture the parking area, the off-, and the on-ramps (Figure 4-2). Polygon

sizes were approximately scaled to the rest area as revealed by the base map of ArcGIS.

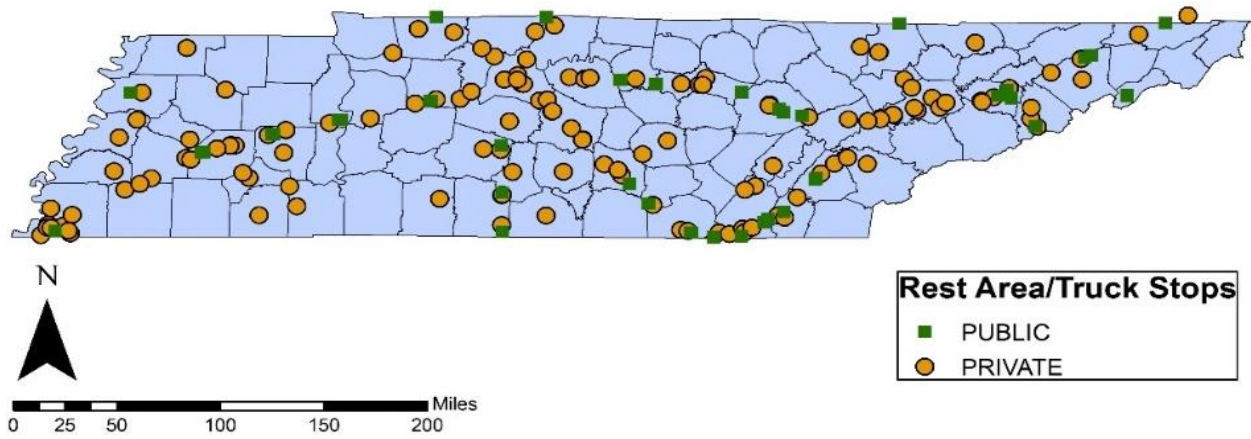


Figure 4-1 Public and Private truck rest areas in Tennessee

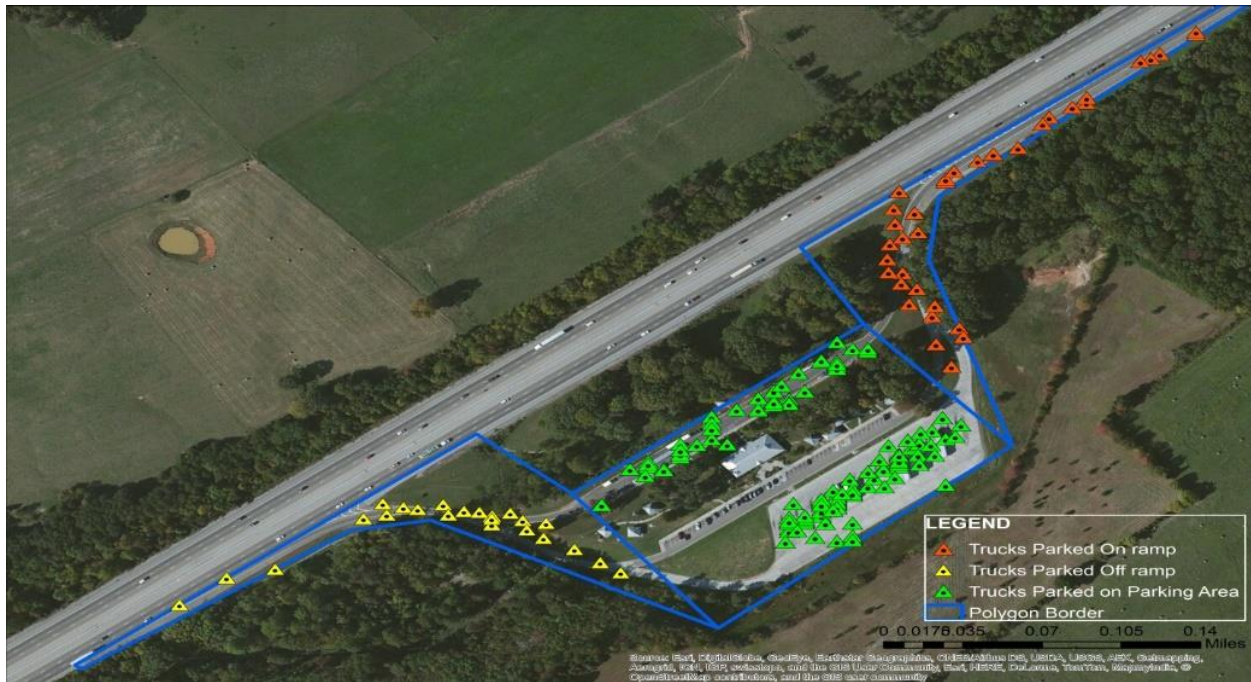


Figure 4-2 Rest area spatial polygon with sample GPS data example

5. Expansion Factors, Truck Parking Utilization and Violations

In this section of the report, we present the methodology used to calculate expansion factors and a discussion of truck parking and violation results. Various performance measures are presented including volume to capacity ratios and violation rates by time of the day, day of the week, and hour of the day. Truck GPS data used in this project accounts for a sample of the total truck population so the team developed expansion factors associated with truck counts and truck count/flow data to expand the GPS sample to estimate the actual number of trucks at the rest areas and ramps.

5.1 Expansion Factors

Expansion factors were developed using TDOT count station data and ETRIMS truck flows. The former data provided hourly counts and thus hourly expansion factors (in addition to daily) were estimated. To estimate the expansion factors, GPS based truck flows were estimated using a 100-ft buffer around each link where a count station was available and for each link on the ETRIMS network in a one-mile radius around each public and private rest area. The expansion factors were then estimated as the ratio of the observed (i.e., count and ETRIMS flows) to the GPS based flows (i.e., ATRI data). Results showed that the count station expansion factors followed a log-normal distribution with a mean of 2.1 and standard deviation of 0.924. In other words, on average, ATRI data represents half the truck population. The ETRIMS count based expansion factors were not consistent, with considerably high mean and standard deviation, so they were discarded and not used in the remainder of this study.

5.2 Truck Parking Utilization and Violation Rates Methodology

In this section, we present the methodology used to determine the number of trucks parked at public and private rest areas and on- and off-ramps. The two major steps for this procedure are as follows:

Step 1: Truck GPS data from ATRI were imported into PostgreSQL and processed for all the rest areas. The dataset was filtered and only GPS points inside rest area polygons were considered. Each row of data (i.e., each GPS ping) contains the unique truck ID, latitude, longitude, speed, heading, and a time stamp. All time stamps were converted to the local time zone. Unique trucks were then projected and intersected with the rest area and ramp polygons to determine the various truck parking performance measures (discussed later in this report).

Step 2: The truck GPS dataset developed from Step 1 was further processed to account for the fact that trucks do not transmit GPS data when their engines are shut down or off. To accomplish that, we examined each truck individually. For every entrance of each truck in a rest area, we followed the truck's GPS footprint until we found the next ping after they turned off their engines. If the time difference between two pings (no-ping issue) was more

than 24 hours and the vehicle appeared in the same parking location, we assumed that the vehicle was not present in that location between the two pings. Obviously, the value of this parameter will affect the results from the analysis. Although some drivers who have reached the 70 hours per week limit may rest for more than 24 hours, that percentage is rather small, and results will not be affected by this assumption. Furthermore, the percentage of observations exhibiting this issue where less than 3 percent of the total population, which further reduces the effects on accuracy of the estimates. In addition to the no-ping issue, a truck observed in a facility for less than 15 minutes was not considered as occupying a parking space. Since the rest area utilization time unit was in hours, a truck that entered or left the rest area in the first or last 15 minutes of an hour was not considered as occupying a parking space for that hour.

5.3 Truck Parking Utilization and Violation Rates Results

Results for public and private parking utilization rates are shown in Figure 5-1 through Figure 5-19. Some general observations and patterns observed are as follows:

- The maximum and average numbers of trucks parked in public and private rest areas are significantly larger between 9 PM and 5 AM (Figure 5-1, Figure 5-2, Figure 5-5, Figure 5-6). Hence the use of these hours as peak hours for truck parking.
- The maximum and average utilization in public and private rest areas are significantly larger between 9 PM and 5 AM (Figure 5-3, Figure 5-4, Figure 5-7, Figure 5-8)
- There is a significant increase in duration of the average parking stop, when parking starts between 3 PM and 11 PM for both public and private rest areas, as well as ramps (Figure 5-11, Figure 5-13, and Figure 5-15). That is to be expected as most drivers stop for the night.
- Violation rates at the on- and off ramps at rest areas in Tennessee vary slightly by the month, day of week, time of day, and location (Figure 5-16 and Figure 5-17) with an average of 7.1 percent and 3.7 percent for the on- and off ramps respectively and a maximum of 19 percent (each) and 32 percent total (which is rather significant). Although the maximum violation rates seem high the maximum number of trucks parked at ramps was equal to 6.
- Ramp parking (Figure 5-9) does not fluctuate by Time of Day (TOD) or month with a maximum of 6 and an average of less than 1.5 trucks parked simultaneously at a ramp. The same can be observed (Figure 5-18 and Figure 5-19) for parking violation percentages (i.e., the maximum and average percentage of trucks parked at the public rest areas and at their corresponding on and off ramps do not fluctuate by TOD).
- The average parking duration on ramps (Figure 5-15) is within the same range as with public and private rest areas with a mean of 3.5 hours and a STD of 4 hours

(for public and private rest areas the mean and STD are 3.37/4.39 hours and 4.54/5.55 hours respectively).

The research team developed a desktop and a web-based data analytics tool using Power BI (www.powerbi.microsoft.com). The desktop and web-based tools can be downloaded/accessed from <https://sites.google.com/view/res2019-16/home>.

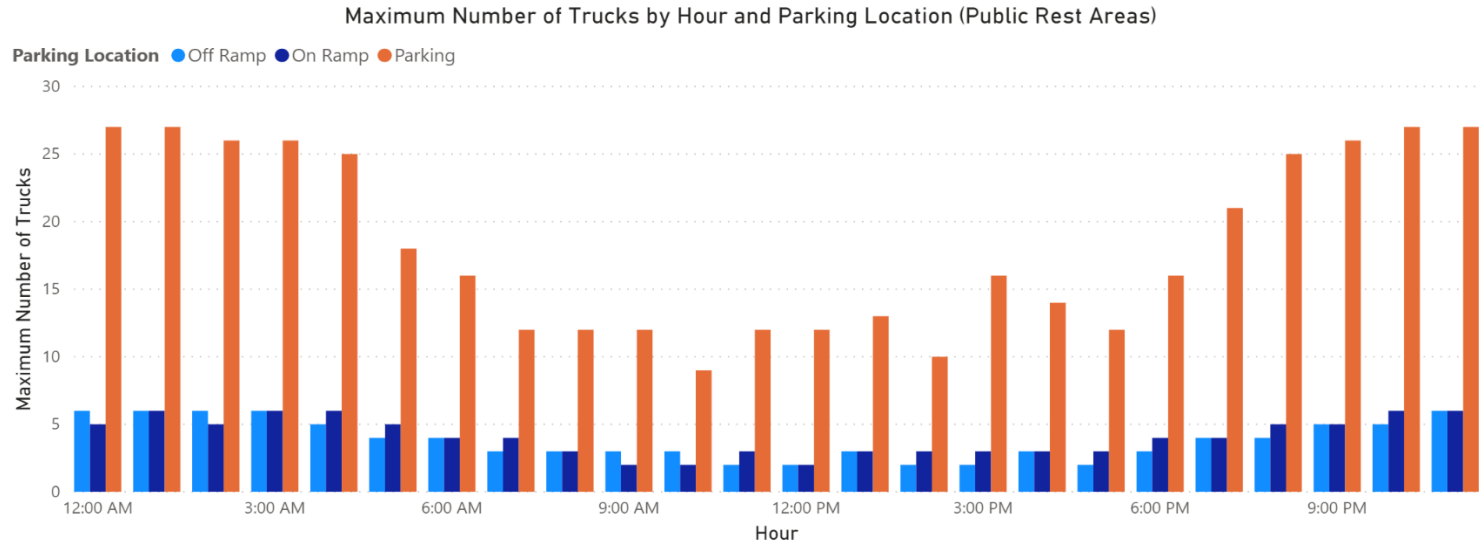


Figure 5-1 Maximum number of trucks by hour and location (public rest areas)

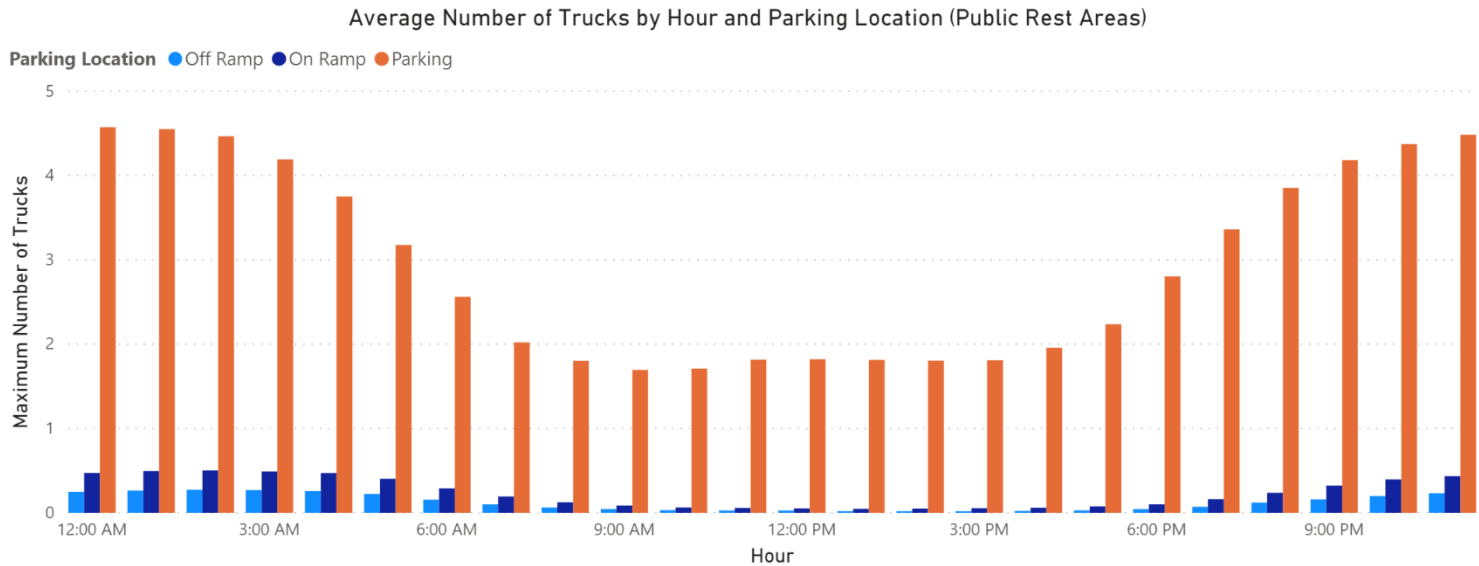


Figure 5-2 Average number of trucks by hour and location (public rest areas)

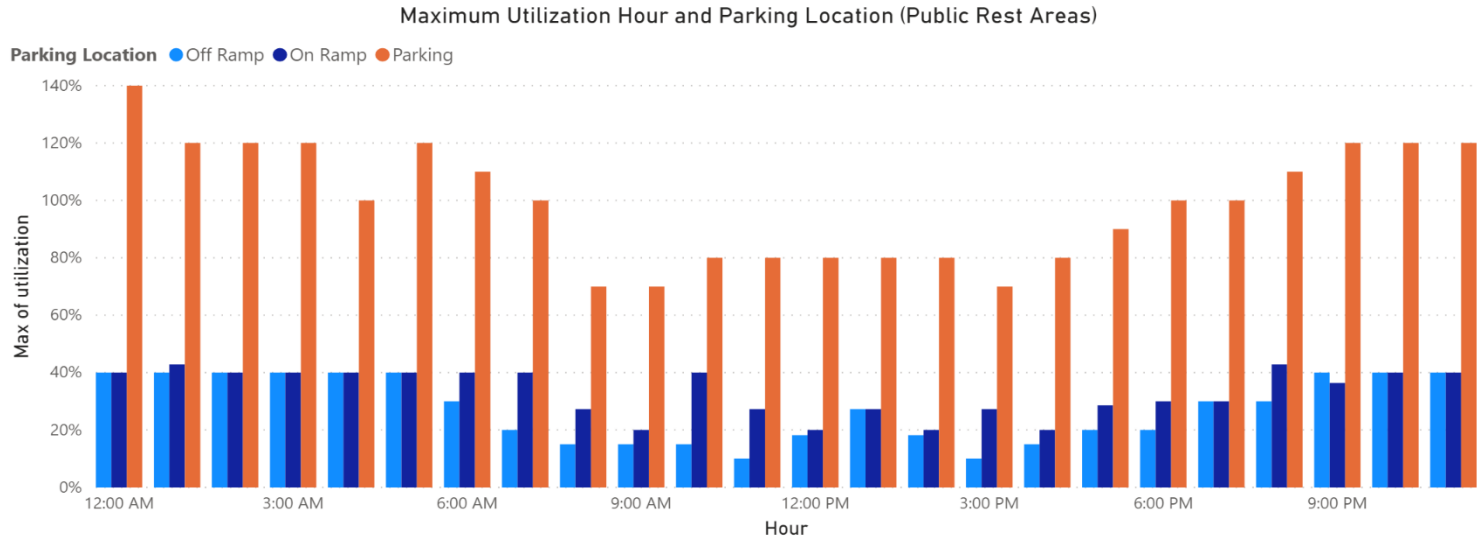


Figure 5-3 Maximum utilization by hour and location (public rest areas)

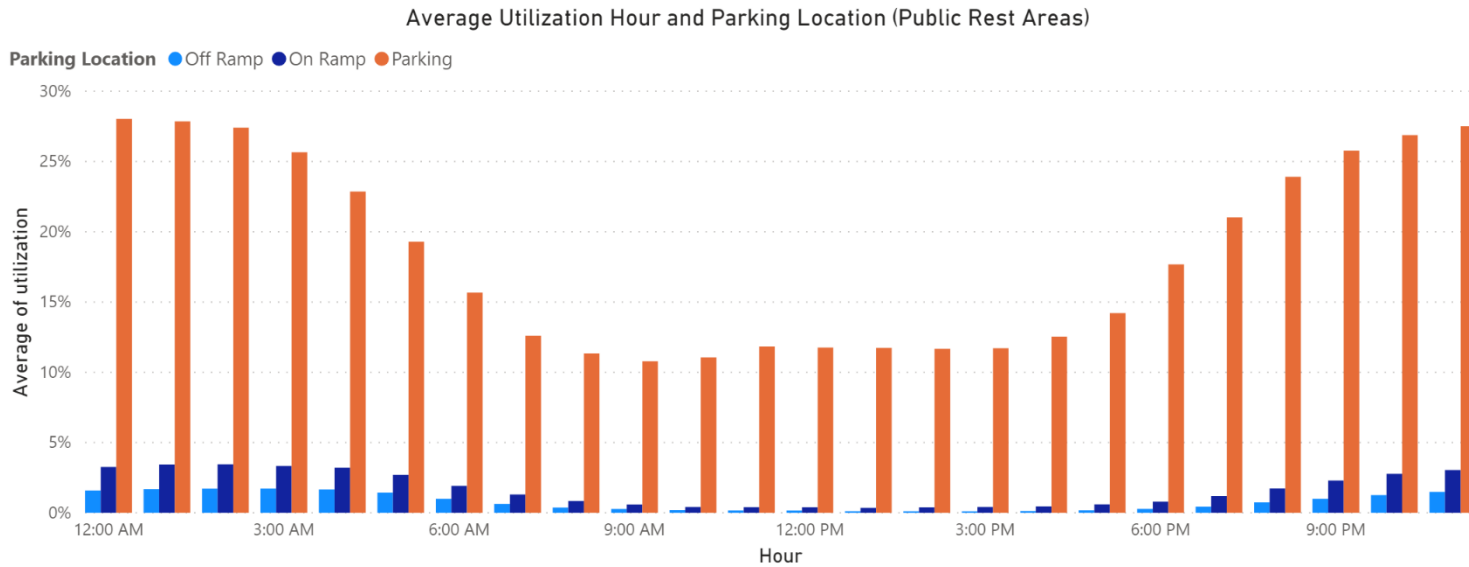


Figure 5-4 Average utilization by hour and location (public rest areas)

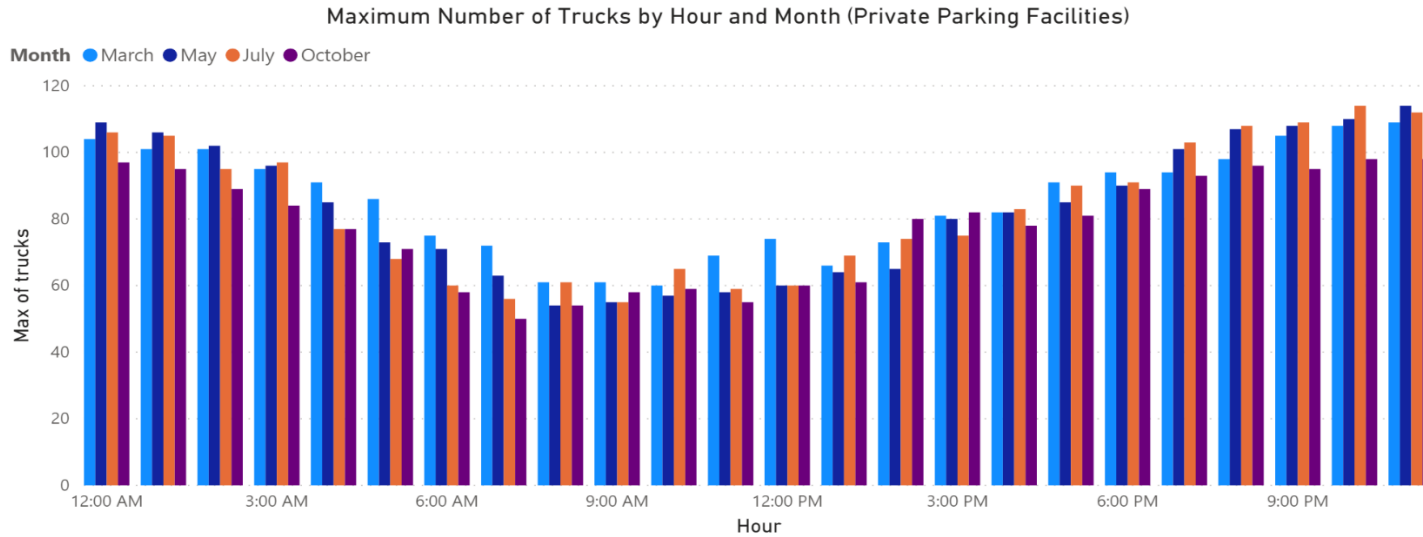


Figure 5-5 Maximum number of trucks by hour and month (private rest areas)

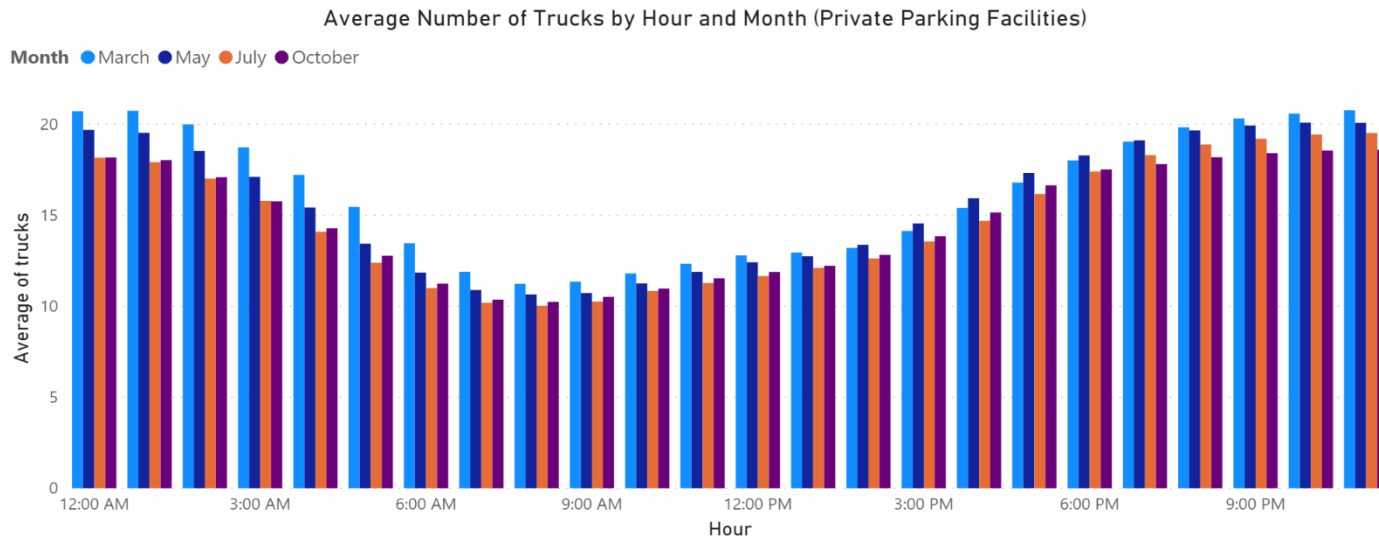


Figure 5-6 Average number of trucks by hour and month (private rest areas)

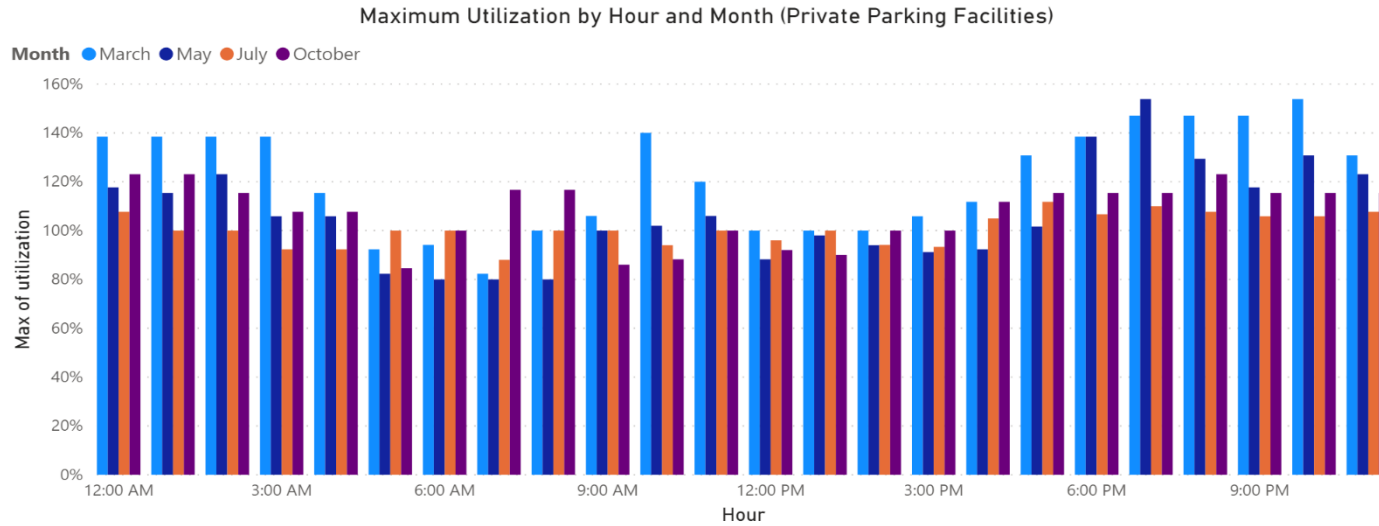


Figure 5-7 Maximum utilization by hour and month (private rest areas)

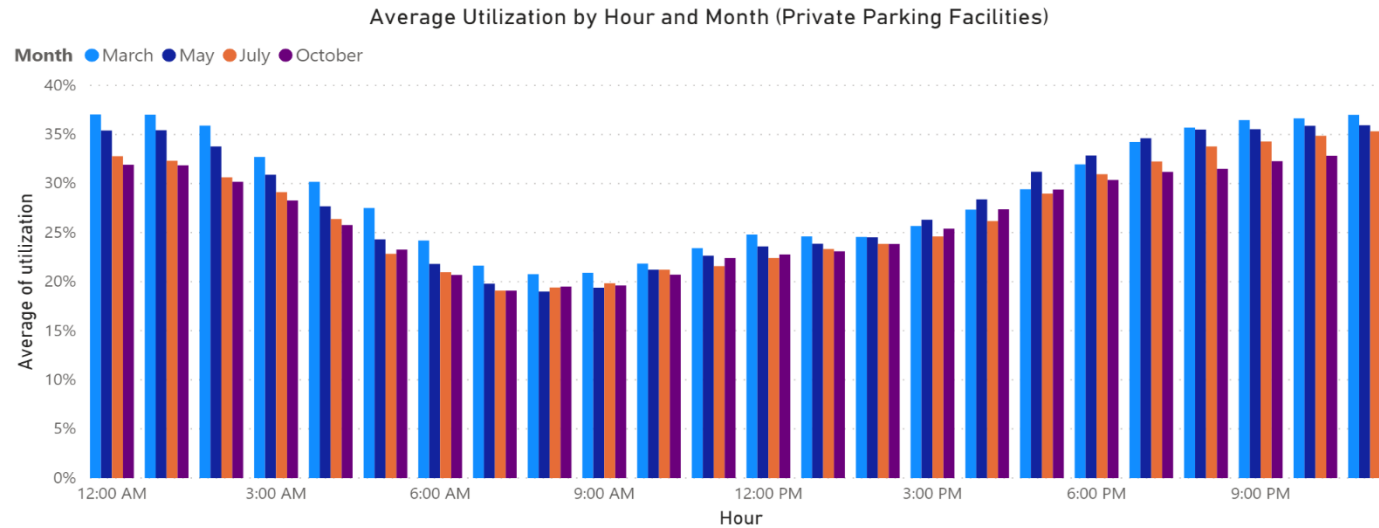


Figure 5-8 Average utilization by hour and month (private rest areas)

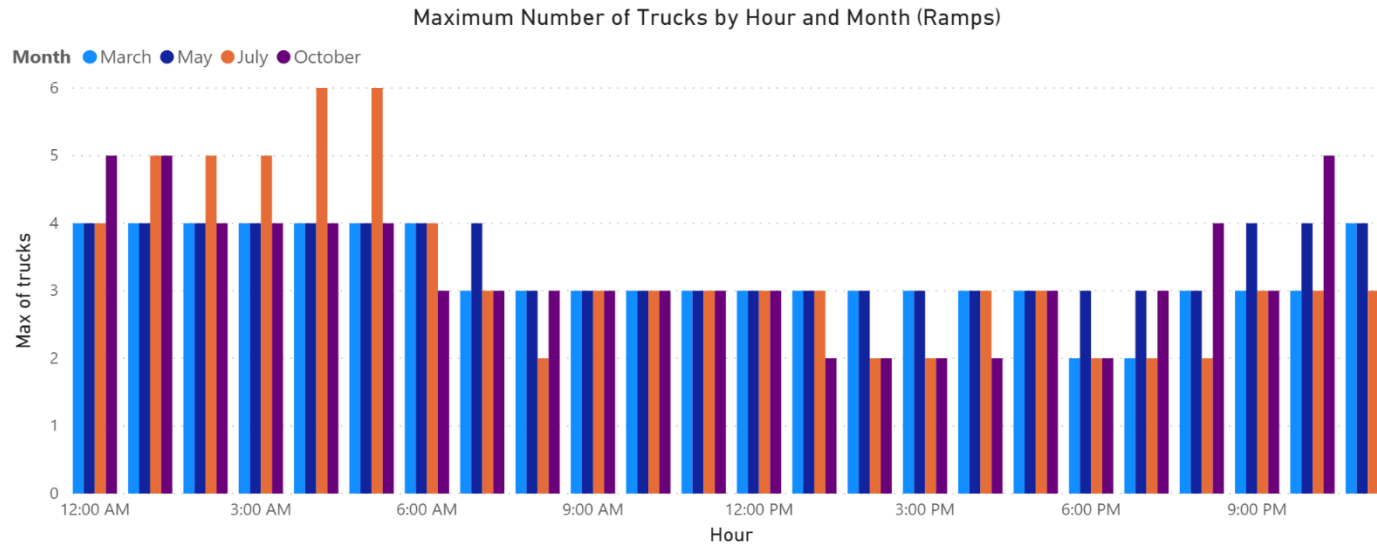


Figure 5-9 Maximum number of trucks by hour and month (all ramps in Tennessee)

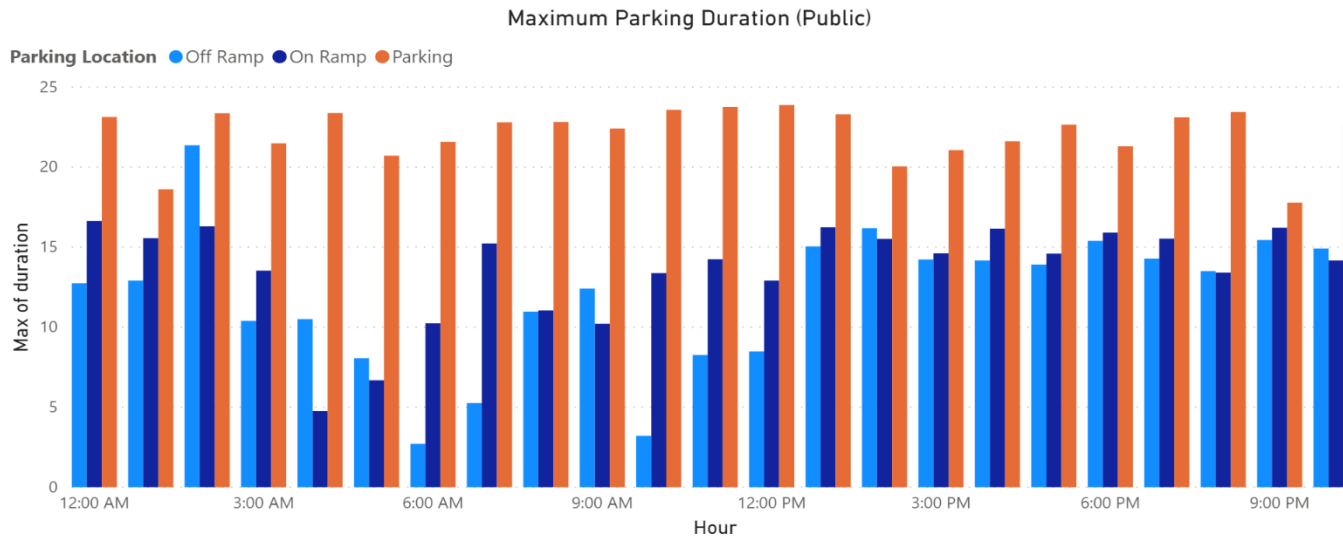


Figure 5-10 Maximum parking duration by start hour and location (public rest areas)

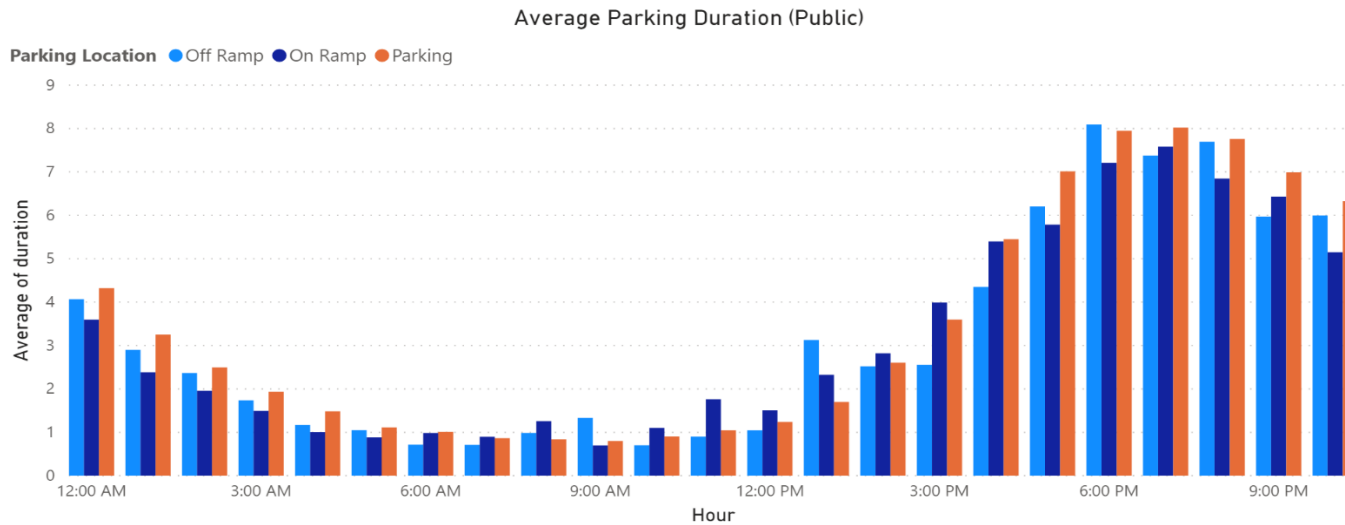


Figure 5-11 Average parking duration by start hour and location (public rest areas)

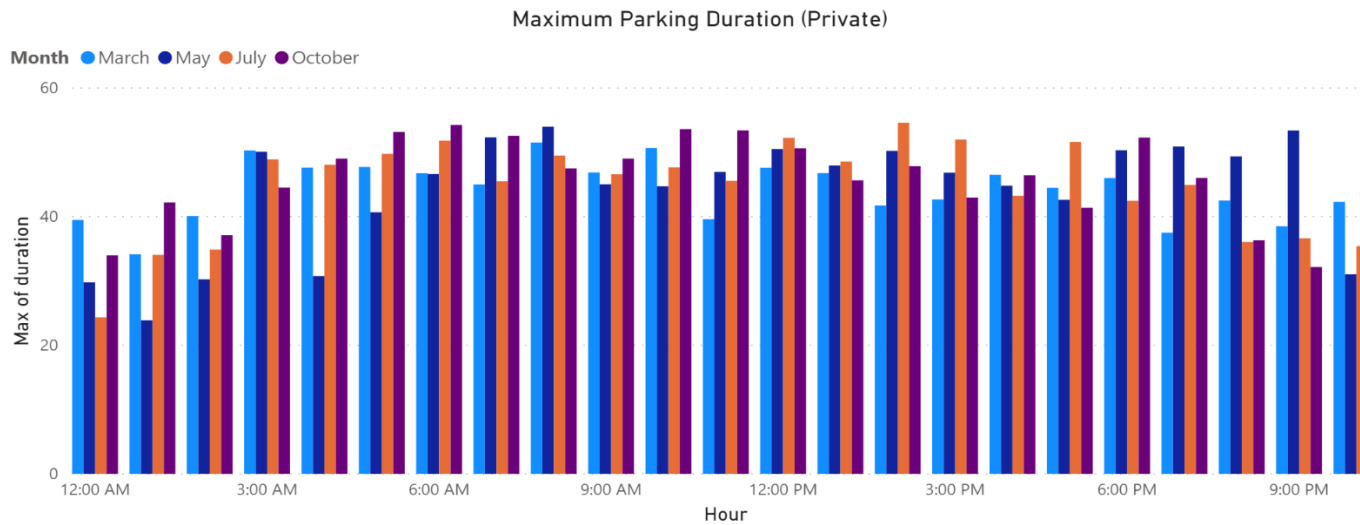


Figure 5-12 Maximum parking duration by start hour and month (private rest areas)

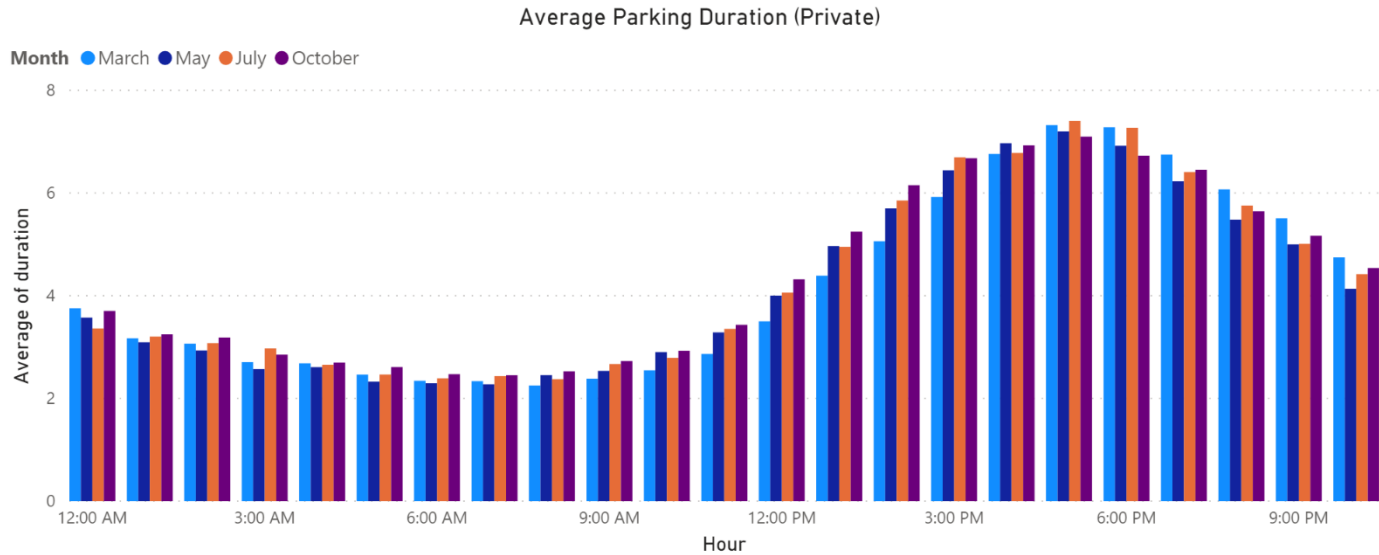


Figure 5-13 Average parking duration by start hour and month (private rest areas)

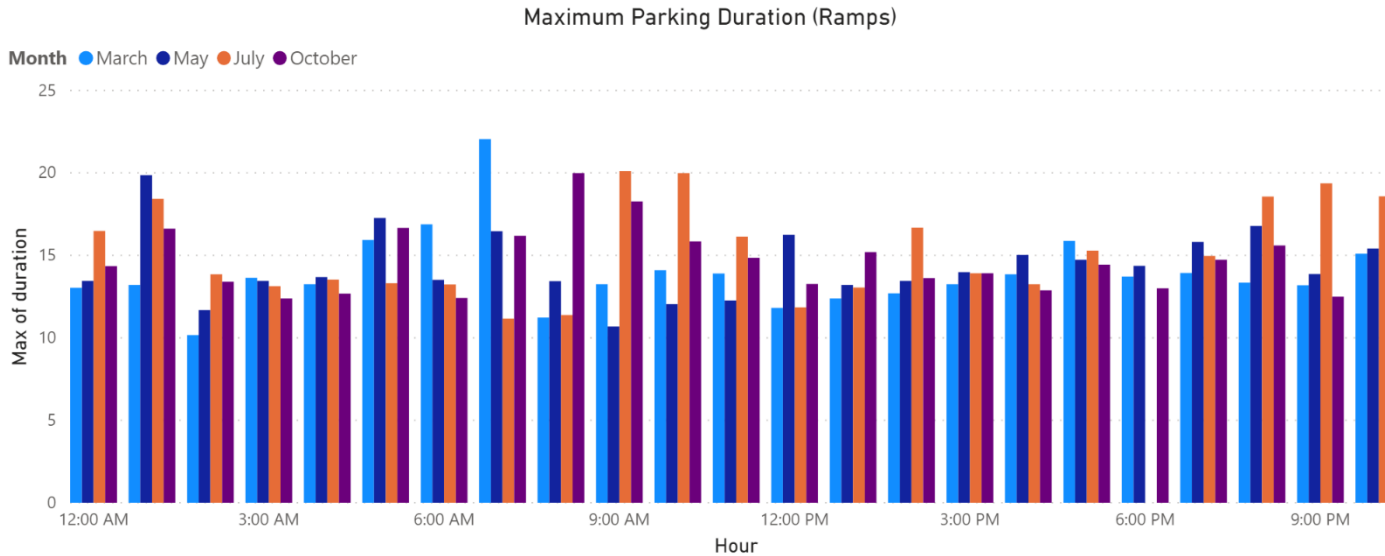


Figure 5-14 Maximum parking duration by start hour and month (all ramps in Tennessee)

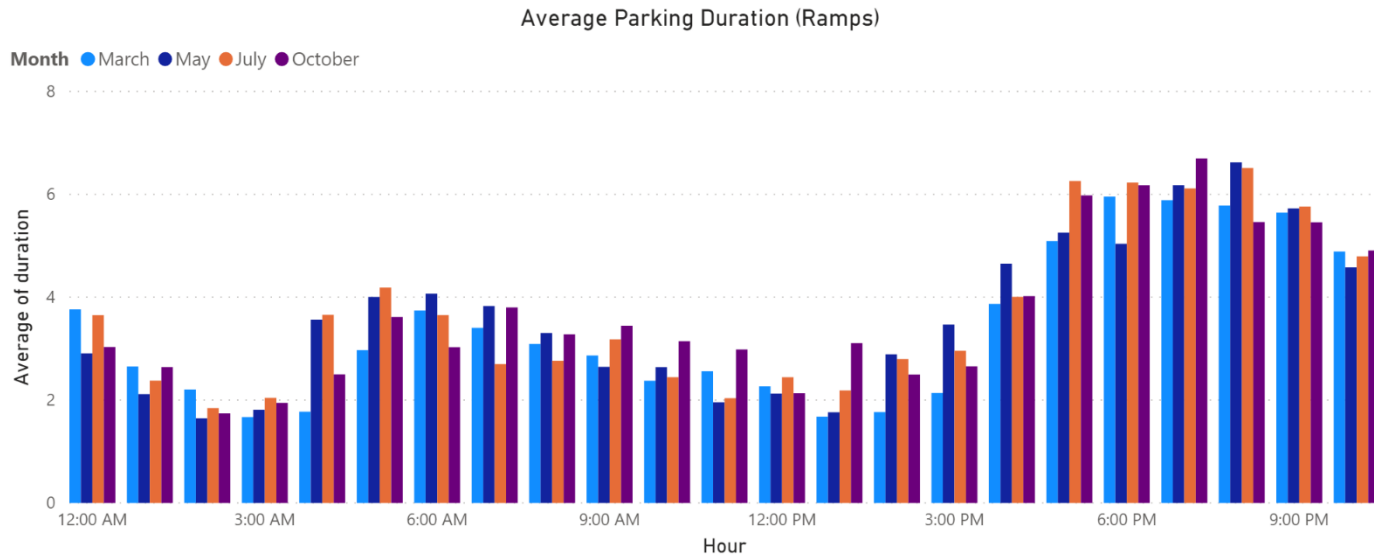


Figure 5-15 Average parking duration by start hour and month (all ramps in Tennessee)



Figure 5-16 Maximum parking violations by month (public rest areas)

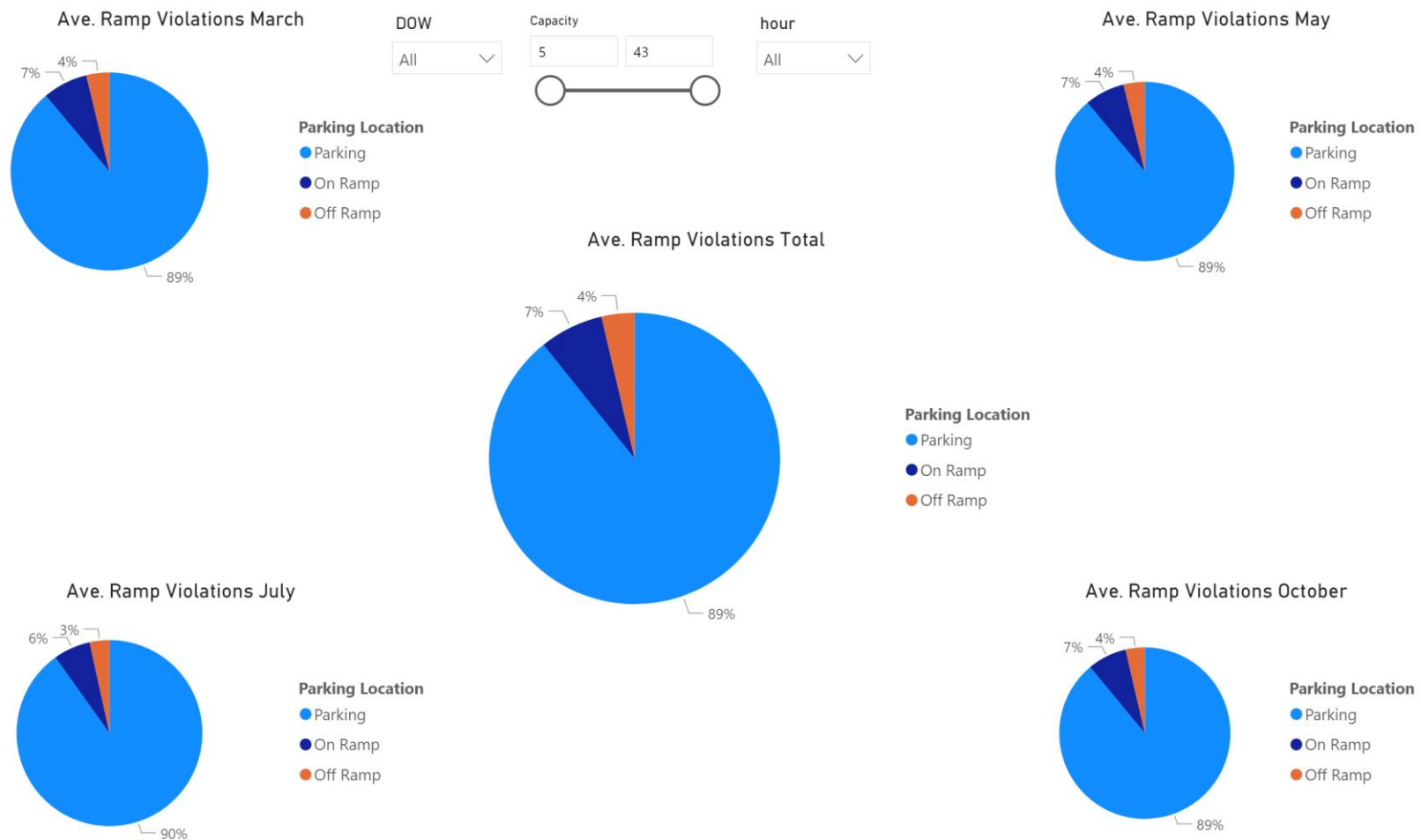


Figure 5-17 Average parking violations by month (public rest areas)

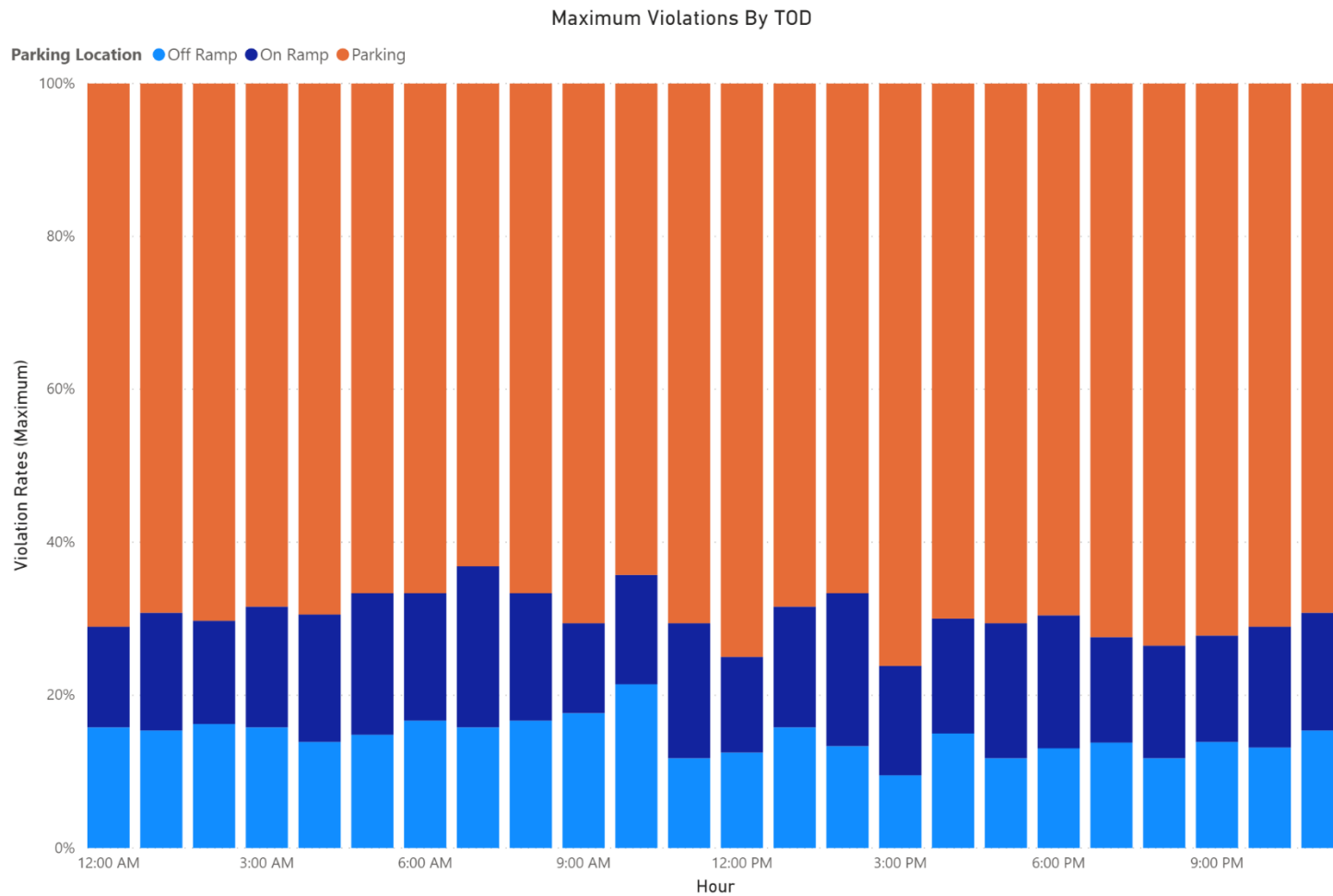


Figure 5-18 Maximum parking violations by TOD (public rest areas)

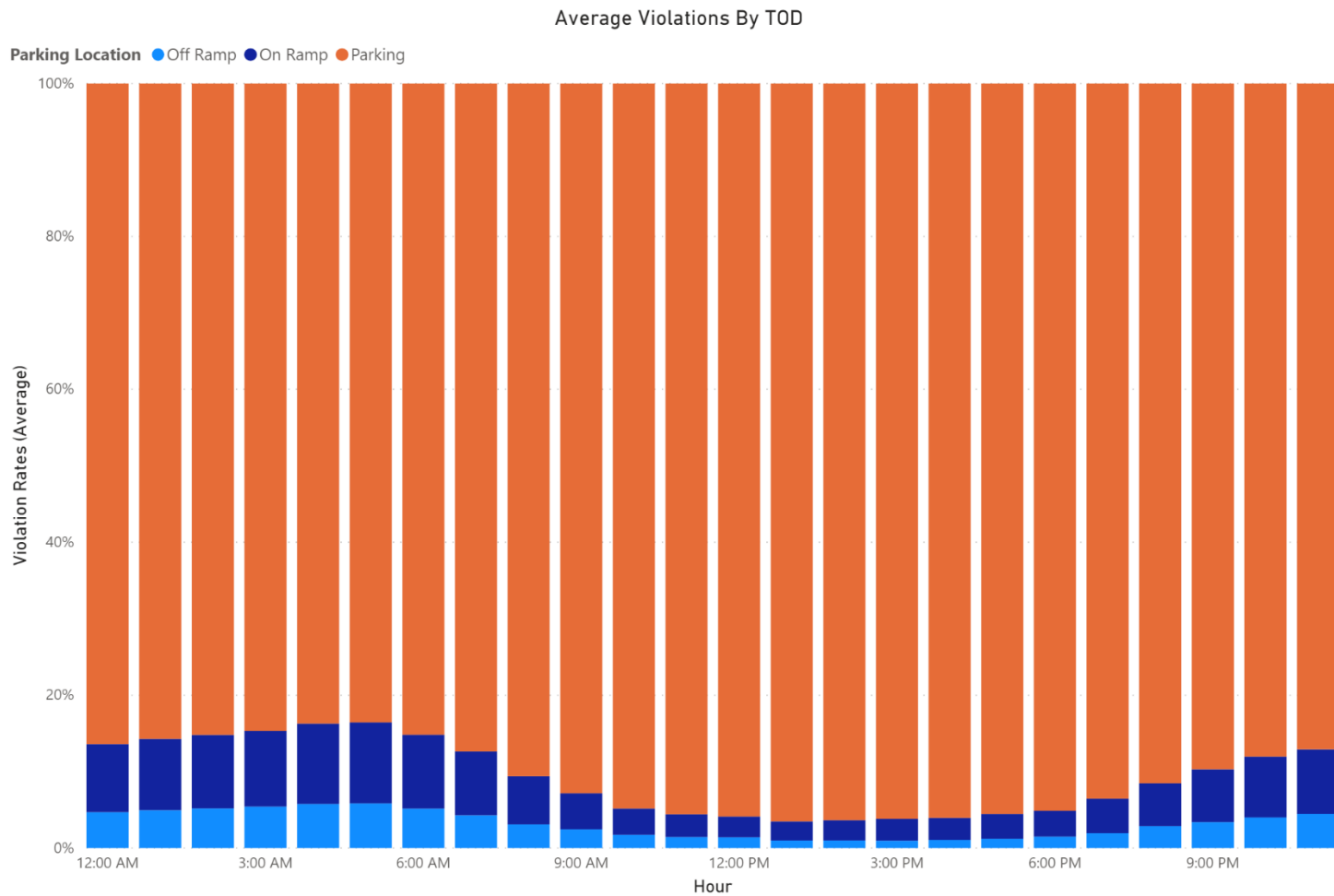


Figure 5-19 Average parking violations by TOD (public rest areas)

6. New Truck Rest Areas and Expansion of Existing Facilities

In this section of the report, we present the methodology developed and applied for selecting new or enhancing capacity of existing truck rest areas in the state of Tennessee. Truck GPS data, truck link flows, and existing rest area utilization rates were utilized to develop various performance measures that can be used to identify locations that need capacity improvement. The following performance measures were estimated for each rest area and used as performance indicators for selecting a rest area as a potential candidate for expansion. In the parenthesis is the corresponding column name of each performance measure in the online and desktop data analytics tools. In this research, the median capacity utilization in year 2035, assuming a 4 percent annual increase for truck parking demand from 2018, was considered and represents an average to worst case scenario.

- **Average utilization (Ave Util):** average utilization by hour.
- **Expanded average utilization (Ave Util with EF):** average utilization multiplied by the mean expansion factor.
- **Expanded average utilization 2 STD (Ave Util with EF_2STD):** expanded average utilization (using the mean plus two STD of the expansion factor).
- **Median utilization (Median Util):** median utilization by hour.
- **Expanded median utilization (Median Util with EF):** expanded median utilization (using the mean expansion factor).
- **Expanded median utilization 2 STD (Median Util with EF_2STD):** expanded median utilization (using the mean plus two STD of the expansion factor).
- **Average utilization peak hours (Ave Uti PH):** average utilization during each rest area's peak hours.
- **Expanded average utilization peak hours (Ave Uti PH with EF):** expanded average utilization for peak hours (using the mean expansion factor).
- **Expanded average utilization peak hours 2 STD (Ave Uti PH with EF_2STD):** expanded average utilization for peak hours (using the mean plus two STD of the expansion factor).
- **Hours of max utilization hour (Hours of Max Util):** number of hours with maximum utilization.
- **Max utilization DOW (Max Util DOW):** day of week with maximum utilization.
- **Max utilization DOM (Max Util DOM):** day of month with maximum utilization.
- **Max utilization Month (Max Util Month):** month of maximum utilization.
- **Time over median utilization (Time Over Median Util):** percentage of time that a rest area operates over the median utilization.
- **Time over 50 percent utilization (Time Over 50 percent Util):** percentage of time that a rest area operates over 50 percent of its average utilization.
- **Time over 75 percent utilization (Time Over 75 percent Util):** percentage of time that a rest area operates over 75 percent average utilization.

A desktop and web-based tool was developed (Figure 6-1 shows a screenshot of the first page of the online tool), to allow TDOT engineers and planners to modify what is deemed as acceptable values for any of the performance measures to identify rest areas that may require additional capacity. With these tools, the user can perform capacity and parking violation analysis using any of the performance measures presented.

6.1 Existing Truck Rest Areas Capacity Expansion

The research team recommends that expanding capacity for public rest areas with more than 70 percent median utilization in 2035 (assuming a 4 percent annual increase) should provide adequate truck parking supply in Tennessee. Table 6-1 lists existing public facilities that meet this requirement along with information on area availability for expansion, existing amenities, and proximity to private rest areas. The research team would also recommend development of new parking facilities at locations with an existing rest area exists in one direction only (shown in Table 6-2). Note that, truck turnout locations have not been included as candidates for capacity expansion as they would include additional cost for amenities (e.g., restrooms, vending machines, tables etc.) and reduce the already limited land availability for truck parking.

designation	Location	Description	Capacity	Ave Util	Ave Util with EF	Ave Util with EF_2STD	M^
Private	108	Love's Travel Stops #344	50	60.87%	128.08%	240.62%	
Private	41	Love's Travel Stops #306	60	56.96%	119.85%	225.16%	
Private	118	Pilot Travel Centers #404	65	55.23%	116.20%	218.30%	
Private	33	Pilot Travel Centers #406	17	55.95%	117.71%	221.14%	
Private	127	Love's Travel Stops #490	90	52.37%	110.20%	207.03%	
Private	42	Pilot Travel Centers #226	34	48.12%	101.26%	190.23%	
Private	65	Love's Travel Stops #244	90	47.72%	100.41%	188.63%	
Private	126	Timeout Travel Center	13	51.28%	107.89%	202.69%	
Private	15	Love's Travel Stops #364	81	44.88%	94.43%	177.41%	
Private	116	Wilco TP #4599	95	44.09%	92.77%	174.29%	
Private	21	Love's Travel Stops #314	112	44.90%	94.47%	177.47%	
Private	48	Pilot Travel Centers #409	60	43.54%	91.60%	172.09%	
Private	47	Love's Travel Stops #369	91	43.18%	90.85%	170.68%	
Private	142	Pilot Travel Centers #149	75	39.87%	83.89%	157.60%	

Parking Facilities

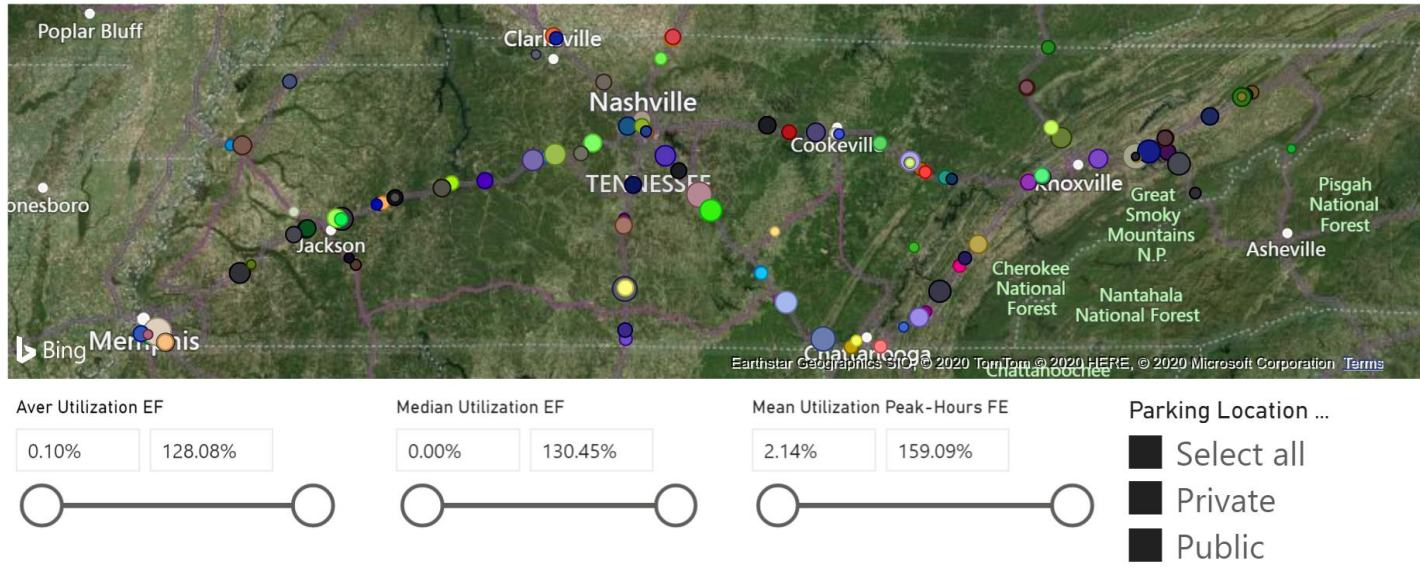


Figure 6-1 Web-based tool for capacity expansion and parking violation analysis

Table 6-1 Candidate public rest areas for expansion based on 2035 projections

ID	Location	Current Capacity	Median Util. (2035)	Area	Amenities	Private parking in proximity with available capacity
3	RA EB I-40 MM73	10	123%	Positive	Yes	No
4	RA WB I-40 MM73	10	123%	Positive	Yes	
7	RA EB I-40 MM130	10	82%	Positive	Yes	No
8	RA WB I-40 MM130	10	82%	Positive	Yes	
9	RA EB I-40 MM170	13	95%	Positive	Yes	No
10	RA WB I-40 MM170	13	95%	Positive	Yes	
11	WC EB I-24 MM 0.5	23	71%	Positive	Yes	No
12	WC WB I-24 MM 0.5	31	106%	Positive	Yes	
16	WC SB I-65 MM121	15	109%	Neutral	Yes	ID: 24, Capacity: 20, MU: 21%
17	WC NB I-65 MM121	21	98%	Neutral	Yes	
25	WC WB I-24 MM160	12	102%	Neutral	Yes	No
26	WC EB I-24 MM172	16	77%	Neutral	Yes	No
41	RA WB I-40 MM426	19	108%	Negative	Yes	No
46	WC WB I-40 MM267	15	82%	Positive	Yes	No
47	WC EB I-40 MM267	15	82%	Positive	Yes	No

RA: Rest Area, WC: Welcome Center, TO: Turnout, MU: Median Utilization in 2035

Table 6-2 Locations for new facilities (location where a rest area exists in only one direction)

ID	Description of Existing Facility	Proposed Location for New Facility
2	REST AREA NB I-155 MM9	REST AREA SB I-155 MM9
40	REST AREA I-40-WB/I-81-SB	REST AREA I-40-EB/I-81-NB

6.2 New Truck Rest Area Locations

In this subsection, we present the methodology developed and results to identify areas with limited or no access to parking spaces for trucks, while taking under consideration utilization rates of neighboring rest areas. The proposed methodology (referred to as truck parking coverage method or TPC) is based on the idea that a rest area with “**adequate remaining capacity**” can cover parking demand within an area of a specific radius around it or that a truck will be able to park if it is located within that area. In this study a radius of 20 miles was considered and road network segments not covered by buffers with radii equal to 20 miles, were defined as segments with “*weak*” truck parking supply. The network considered for this analysis was a subnetwork of ETRIMS (Figure 6-2) consisting of interstates I-24, I-26, I-40, I-55, I-65, I-75, I-81 and “*auxiliary*” interstate highways I-124 (US 27) in Chattanooga, I-140 in Knoxville and Alcoa, I-155 in Dyersburg, I-240 in Memphis, I-275 in Knoxville, I-440 and I-840 in Nashville and I-640 in Knoxville. To adequately provide truck parking supply and ensure the State of Tennessee is prepared for future truck parking needs, projected utilization rates for 2035 were developed. Per ATRI’s recommendation, the annual growth rate for truck parking was set to 4 percent. Based on that rate, utilization rates were developed using the 2018 data and used to perform the analysis based on the TPC method.

Three different cases of “**adequate remaining capacity**” were considered for each public and private parking facility using the median utilization in 2035: i) 40 percent (i.e., a median utilization rate projected for 2035 of less than 60 percent (combination A), ii) 30 percent (i.e., a median utilization rate projected for 2035 of less than 70 percent (combination B), and iii) 20 percent (i.e., a median utilization rate projected for 2035 of less than 80 percent (combination C) respectively. If a parking facility met this utilization criterion then it was considered as having “**adequate remaining capacity.**” Results of the analysis are summarized in Figure 6-3 through Figure 6-5. All three figures also show the locations of existing truck parking facilities identified as candidate locations for expansion. These results indicate that there are two segments of the interstate network (I-40 between Jackson and Nashville and I-75 north of Knoxville) that lack adequate truck parking capacity. Both segments do not necessarily require the construction of new facilities as existing truck parking facilities that are candidates for expansion are present and would address the capacity shortage and reduce capital costs.

The research team developed an online tool that can be accessed from: <https://sites.google.com/view/res2019-16/home>, where the same analysis can be performed for years 2018, 2020, 2025, and 2035 with three different radii (10, 20 and 30 miles) and multiple performance measures (e.g., peak hour utilization, average utilization etc.). The rationale for developing the tool was for TDOT to be able to perform their own analysis with various scenarios.

Interstate Network in Tennessee

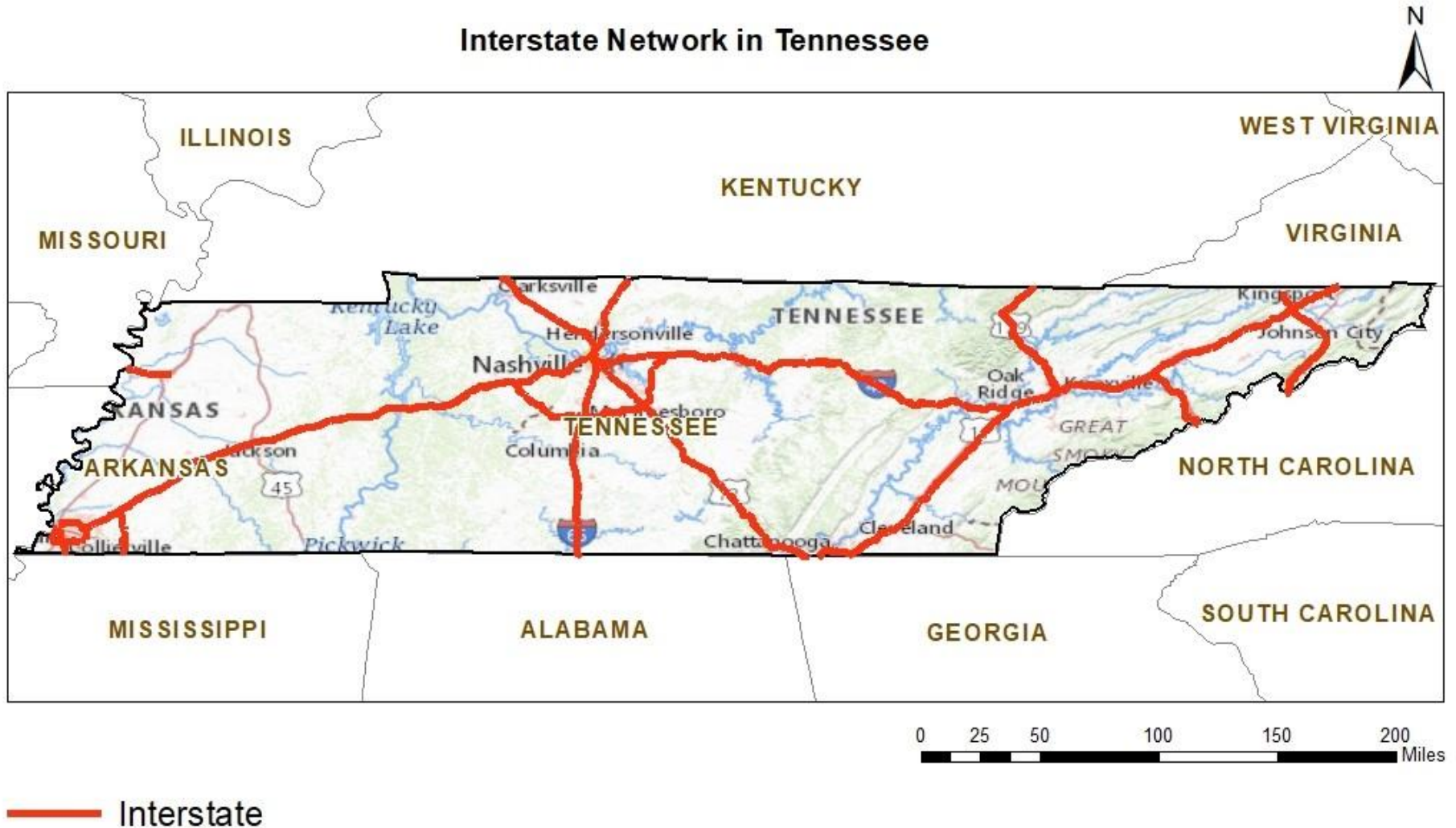


Figure 6-2 Tennessee Interstate Network

**Interstate Segments in Need of Additional Parking
Adequate Median Utilization 60% & 20-mile buffers (2035 projection)**



- Interstate
- 20-mile buffer
- Candidate rest areas for expansion
- Locations for new rest areas (where a rest area exists in only one direction)
- 99 Public rest area ID

Figure 6-3 Median utilization (2035 projection – 4% annual increase rate) less than 60% with 20-mile buffer, interstate network overlap

**Interstate Segments in Need of Additional Parking
Adequate Median Utilization 70% & 20-mile buffers (2035 projection)**



- Interstate
- 20-mile buffer
- Candidate rest areas for expansion
- Locations for new rest areas (where a rest area exists in only one direction)
- 99 Public rest area ID

Figure 6-4 Median utilization (2035 projection – 4% annual increase rate) less than 70% with 20-mile buffer, interstate network overlap

**Interstate Segments in Need of Additional Parking
Adequate Median Utilization 80% & 20-mile buffers (2035 projection)**



- Interstate
- 20-mile buffer
- Candidate rest areas for expansion
- Locations for new rest areas (where a rest area exists in only one direction)
- 99 Public rest area ID

Figure 6-5 Median utilization (2035 projection – 4% annual increase rate) less than 80% with 20-mile buffer, interstate network overlap

6.3 Additional Consideration/Recommendations

As previously discussed in this report and from the results of the data analysis and survey, one of the main issues with truck parking in Tennessee seems to be the lack of preparation from the truckers to plan ahead for parking and for the need of parking in the vicinity of major intermodal freight clusters where truckers can park and wait before a pick-up or delivery. The research team thus recommends that Tennessee invests in technology that would provide truckers with (close to) real time information on truck parking availability (see Golias et al., 36).

7. Conclusions

The objective of this research was to provide TDOT with guidance on truck parking issues and opportunities by identifying parking needs (i.e., addition of capacity and/or construction of new facilities); developing truck parking violation rates (i.e., truck parking at on- and off- ramps); and developing/applying a methodology to identify candidate locations for new truck parking facilities in the state of Tennessee.

As part of this research, a data analytics web-based tool along with its desktop version were developed. Both tools can be used to produce various truck parking performance measures including volume to capacity ratios and violation rates by time of the day, day of the week, roadway segments between locations where candidate truck parking facilities may be located and various other measures. The research generated examples of the capabilities of each webpage, as well as technical snapshots to demonstrate the capabilities of the data. The proposed research developed a methodology to identify locations for the construction of new rest areas. The methodology is based on the idea that a rest area with “adequate remaining capacity” can cover parking demand within an area of a specific radius around it or that a truck will be able to park if it is located within that area. The research incorporated the methodology in a GIS-based online tool to assist in the selection of new truck parking locations. Multiple criteria are available to identify areas with limited or no access to parking for trucks, while taking into consideration parking utilization rates of neighboring locations based on the coverage of existing locations. The GIS-based tool contains all the processed data presented in this report, but also allows the user to create buffer areas around the parking facilities and identify parts of the network (ETRIMS network) not covered by these facilities using different metrics.

The research team used the online GIS-based tool to identify existing rest areas for capacity expansion and locations on the interstate system for construction of new rest areas. Three different cases of 20, 30, and 40 percent of “adequate remaining capacity” using the median utilization in 2035 and a 20-miles radius were considered for the existing public and private parking facilities. An annual truck parking demand increase of 4 percent (from the 2018 base year) was assumed. Fifteen existing rest areas were identified as candidates for capacity upgrades, and two segments of the interstate network (I-40 between Jackson and Nashville and I-75 north of Knoxville) that would benefit from

construction of new rest areas. Based on the analysis the research team also recommended the addition of new facilities in two locations where a rest area exists on one direction of the network. These capital investments should be combined with technology investments to allow truckers to plan for parking (although results from the survey show that a significant number of truckers do not use any technology and do not plan ahead results that are similar to the survey by Cherry et al, 2012 (36).

One drawback of the proposed study was its reliance on GPS data, which represents a sample of the actual truck demand. The research team addressed the issue by developing expansion factors which should be used with caution as they are created using a small sample size. The research team strongly recommends that a larger study covering multiple neighboring states (AR, MS, AL KY, GA) and a longer time period of GPS data is performed to obtain more robust and reliable results and identify collaboration opportunities between the states. It is also highly recommended that further analysis is performed to include accident analysis (involving trucks or during presence of illegal parking), freight facility locations, commodity flows (disaggregate at zip code level), and trip types (long haul, short haul, drayage etc.). Such a study would be a major undertaking but the benefits for the State DOTs involved and the trucking industry would be significant.

By focusing on infrastructure investment at both federal and state levels, this study can provide a blueprint for identifying truck parking strategies that provide the greatest value to the public and private sectors. More specifically, by addressing strategic truck parking needs through the utilization of truck GPS data, policy makers can play an integral role in supporting hours-of-service compliance, unauthorized truck parking, safety, and the economic gains that come from highly efficient supply chains – particularly those that are becoming increasingly reliant on the e-commerce evolution. Recognizing that truck parking is one of the most influential factors for route selection decisions, and that lack of truck parking has safety and economic ramifications, this study can be a key component for freight planning and investment activities, as well as a template on how to utilize GPS data to produce various performance measures regarding truck parking. It is the researchers' opinion that innovative use of GPS data for truck parking analysis can become a "*best practice*" for policy makers, DOT's and researchers.

8. REFERENCES

1. The American Transportation Research Institute. Critical Issue in the Trucking Industry. 2018.
2. North Carolina Statewide Multimodal Freight Plan: Pipeline and Hazardous Material Profile. NCDOT. 2017.
3. North Central Texas Council of Governments. Truck Parking Study A Freight North Texas Study. 2018.
4. Virginia Department of Transportation. Virginia Truck Parking Study. 2015.
5. The North Jersey Transportation Planning Authority. An Assessment of Potential Locations for Truck Rest Areas in Northern New Jersey and the Port District. 2008.
6. North Jersey Transportation Planning Authority. North Jersey Truck Rest Stop Study Refinement and Action Plan-Final Report. 2009.
7. MID-AMERICA Freight Coalition. An Evaluation of Vacant Urban Land for Truck Parking About the Mid-America Freight Coalition (MAFC). 2017.
8. Foutz, L., and Martin Engineering. Comprehensive Parking Study for Freight Transport in Miami-Dade County. No. 305, 2010.
9. Kansas Statewide Freight Network Truck Parking Plan. 2016.
10. Phelan, T. National Coalition on Truck Parking Activity Report. 2016.
11. MAASTO TPIMS Project Concept of operations. 2016.
12. Fairbank, T. Study of Adequacy of Commercial Truck Parking Facilities – Technical Report Prepared for Federal Highway Administration.
13. Srivastava, P., B. X. Wang, and T. M. Adams. Geo-Spatial Analysis of Truck Parking Needs. *Journal of Transportation Systems Engineering and Information Technology*, Vol. 12, No. 4, 2012, pp. 93–105.
14. Gingerich, K., Maoh, H., Anderson W. Border Crossing Choice Behavior of Trucks along Trade Corridor between Toronto, Ontario, Canada, and Chicago, Illinois. *Transportation Research Record*, Vol. 2477, No. 2477, 2015, pp. 85–92.
15. Federal Highway Administration. Model Development for National Assessment of Commercial Vehicle Parking. 2002.
16. Garber, N., Wang, H., Charoenphol, D. Estimating the Supply and Demand for Commercial Heavy Truck Parking on Interstate Highways: A Scenario Study of I-81 in Virginia. 2002.
17. Garber, N., Wang, H. Final Report Estimation of the Demand for Commercial Truck Parking on Interstate Highways in Virginia. 2004.
18. Wilbur Smith and Associates. Study of Rest Area Truck Parking. FHWA Report No. OH-09/006. OHIO Department of Transportation and Federal Highway Administration, Washington, D.C. 1990.
19. Haque, K., S. Mishra, R. Paleti, M. M. Golias, A. A. Sarker, K. Pujats. Truck Parking Utilization Analysis Using GPS Data. *Journal of Transportation Engineering Part A: Systems*, Vol. 143, No. 9, 2017.
20. Golias, M., J. Dobbins, J. Short, and Z. Johnson. GPS / GIS Analysis of Tennessee

Truck Trips. 2012.

21. Atlanta Regional Truck Parking Assessment Study Draft Final Report. 2018.
22. Torrey, W. F., Murray, D. Managing Critical Truck Parking Tech Memo #2: Minnesota Scenario Study-Utilizing Truck GPS Data to Assess Parking Supply and Demand. 2017.
23. Foutz, L., Marlin Engineering. Comprehensive Parking Study for Freight Transport in Miami-Dade County. 2010.
24. Higgins, C., Chiu Y., Bai, Y. Methodological Framework Development for Evaluating Highway Truck Rest area and Capacity Expansion. 2015.
25. Bayraktar, M. E., Arif, F., Ozen, H., Tuxen, G. Smart Parking-Management System for Commercial Vehicle Parking at Public Rest Areas. *Journal of Transportation Engineering*, Vol. 141, No. 5, 2015, pp. 1–16.
26. Anderson, E., Hernandez, J., Jessup, S., North, E. A random parameters binary logit analysis of truck driver opinions in the Pacific Northwest. 2018.
27. Boris, C., Johnson, M. Managing Critical Truck Parking Tech Memo #1: Commercial Driver Perspectives on Truck Parking. 2015.
28. Adams, T. Low Cost Strategies to Increase Truck Parking in Wisconsin. 2009.
29. Washington State Department of Transportation. Washington State Truck Parking Study. 2016.
30. Federal Highway Administration. Commercial Vehicle Driver Survey: Assessment of Parking Needs and Preferences-Final Report. 2002.
31. American Transportation Research Institute. Managing Critical Truck Parking Scenario Study – Real World. 2016.
32. Giron-Valderrama, G., Ivanov, B., Goodchild, A. Safe Truck Parking in PacTrans Interstate Corridors: I-5 and I-90. 2018, p. 66p.
33. U.S Department of Transportation. Freight Facts and Figures. Bureau of Transport Statistics, Vol. 11th edition, 2015, pp. 1–11155.
34. Chatterjee, A, Wegmann, F J, Clarke, D B. TRUCK PARKING AND SAFETY IN REST AREAS IN TENNESSEE. In proceedings of ITE 2001 Annual Meeting, Chicago IL, 2001
35. Texas Department of Transportation. Texas Statewide Truck Parking Study. 2020.
36. Golias, M., Mishra, S., Flaskou, M., Jordan, S. Tennessee Smartpark Pilot. 2017.
37. Cherry, C., Boggs, A., Franceschetti, N., Ling, Z., Nambisan, S. Truck Parking Facilities and Ramp Parking: Role of Supply, Demand, and Ramp Characteristics. A research report to the Tennessee Department of Transportation Project RES2016-07. 2016.

9. APPENDIX A: SURVEY INSTRUMENT

The American Transportation Research Institute (ATRI), the not-for-profit research arm of the trucking industry, is assisting the University of Memphis, the University of Tennessee, Knoxville, and the Tennessee Department of Transportation, in better understanding the truck parking issues that truck drivers face. ATRI is now seeking truck driver input on the attached survey. The survey data will be used to help improve truck parking in the state of Tennessee. All responses to this survey will be kept strictly confidential and will only be reported in aggregate form. **Due to the sensitivity of this research, under NO circumstances will we release any of your personal or organizational information.**

1. How often do you need truck parking in Tennessee?
 - Less than once a week
 - Once a week
 - 2-4 times a week
 - 5-6 times a week
 - Everyday
 - Never

NOTE: If answer is "Never" survey is complete.

Tennessee State Truck Parking

1. How do you usually plan to find parking?
 - I use internet or smartphone applications
 - I call travel centers to ask about parking availability
 - I always park at the same place
 - I find nearest parking within the hour of HOS limit and keep driving until I find parking
2. If you use internet or smartphone applications which application do you use:
 - Trucker Path
 - Park My Truck
 - Road Breakers
 - Truckbubba
 - DAT Trucker
 - Other (please define): _____
3. How far in advance do you plan your parking location?
 - <1 hour
 - 1-3 hours
 - 4-8 hours
 - Before my driving shift
4. On average, how long does it take for you to find truck parking in Tennessee?
 - Less than 15 minutes
 - 15 – 30 minutes
 - 30 minutes – 1 hour
 - More than 1 hour

5. Please indicate up to 3 locations in Tennessee in which finding safe, available parking is most difficult (in descending order of difficulty)?

Corridor	Mile Marker/Town/City

6. How often do you personally experience the following in Tennessee (check one response for each row)?

Condition	Never	Rarely	Occasionally	Often	Always
I can find parking at private truck parking facilities (e.g., Pilot)					
I can find parking at public rest areas					
I can only find parking on ramps or shoulders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Parking only available in unsafe locations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shipper/Receiver permits on-site parking outside of appointment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shipper/Receiver loading and unloading delays exceed one hour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I change my operations (route or schedule) because of parking challenges in Tennessee					

7. Please indicate how easy it is to find truck parking in Tennessee with the following scenarios. (check one for each row)

Scenario	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
It is easy to find truck parking in Tennessee in comparison to the surrounding states (North Carolina, Georgia, Alabama, Mississippi, Arkansas, Missouri, Kentucky and Virginia)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is easy to find truck parking in Tennessee for the mandatory Hours of Service breaks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is easy to find truck parking in Tennessee for short periods of time while waiting to make a scheduled delivery.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. Do you have any additional thoughts on finding convenient, safe and legal truck parking in Tennessee?

Demographics

1. Gender
 - Female
 - Male
 - Prefer not to respond

2. What is your age?
 - Younger than 25
 - 25-44
 - 45-64
 - 65+

3. In what segment of the trucking industry do you primarily operate? (check one)
 - For-hire
 - Private
 - Don't know

4. If for-hire, which sector best describes your operation? (check one)
 - Truckload
 - Less-than-truckload
 - Flatbed
 - Tanker
 - Express / Parcel Service
 - Intermodal Drayage
 - Other (please specify): _____
 - Don't know

5. Which of the following best describes your employment: (check one)
 - Employee driver
 - Owner-operator (O-O) with own authority
 - O-O / Independent Contractor leased to a motor carrier
 - Fleet executive / manager
 - Other: _____

6. If you are an employee or leased driver, how many total tractors does your fleet operate? (check one)
 - ≤ 5
 - 6-20
 - 21-500
 - 501-1,000
 - 1,001-5,000
 - 5,001+

7. In general, what is your overall average length of haul? (check one)
 - Local (less than 100 miles per trip)
 - Regional (100-499 miles per trip)
 - Inter-regional (500-999 miles per trip)
 - Long-haul (1,000+ miles per trip)

- Don't know
8. What is the primary vehicle configuration that you typically operate? (check one)
- 5-axle Dry Van
 - 5-axle Refrigerated Trailer
 - 5-axle Flatbed
 - 5-axle Tanker
 - Straight Truck
 - Longer Combination Vehicles (Doubles, Triples, etc.)
 - Other (please specify): _____