

Truck Parking Facilities and Ramp Parking: Role of Supply, Demand, and Ramp Characteristics

**A research report to the Tennessee Department of Transportation
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Authors:

Christopher Cherry, Ph.D. (PI)

Associate Professor
Department of Civil and Environmental Engineering
University of Tennessee, Knoxville
851 Neyland Drive, Knoxville, TN 37996
321 John D. Tickle Building
Tel: 865-974-7710; Email: cherry@utk.edu

Alexandra Boggs

Graduate Research Assistant
Department of Civil and Environmental Engineering
University of Tennessee, Knoxville
Tel: 813-478-5046; Email: aboggs6@vols.utk.edu

Nicolo Franceschetti

Undergraduate Research Assistant
University of Tennessee, Knoxville
Tel: 540-324-8477; Email: nfrance2@vols.utk.edu

Ziwen Ling

Graduate Research Assistant
Department of Civil and Environmental Engineering
University of Tennessee, Knoxville
Tel: 865-686-2386; Email: zling@vols.utk.edu

Shashi Nambisan, Ph.D., P.E.

Professor
Department of Civil and Environmental Engineering
University of Tennessee, Knoxville
Tel: 865-974-7706; Email: shashi@utk.edu

Project Manager:

Brad Freeze, P.E.

Director, Traffic Operations Division
Tennessee Department of Transportation
Tel: 615-741-5017; Email phillip.b.freeze@tn.gov

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16. Abstract Faced with increasing commercial vehicle (CMV) traffic and static revenue, public agencies cannot contend with providing adequate public parking for CMVs leading to overcapacity facilities and resulting in ramp parking. This study analyzes Tennessee's primary freeways to assess truck facilities in addition to inventorying the usage of ramps shoulders for overnight parking during the peak hours of weekdays. The authors used CMV drivers' perspectives and behaviors on the parking problem through a survey along with examining ramp characteristics and ramp parking to identify factors that influence illegal ramp parking. The results illustrate that among the 94 truck facilities, 73 locations had a utilization rate of 75% or greater with the average of 89.9%. We examined 854 rural ramp attributes as well as the parking of 295 CMVs along 134 ramps. Diamond interchanges, wider shoulder, absence of no parking on shoulder signs, smaller width and fewer lanes near the intersection, and longer ramps were significant factors of parked CMVs. Through CMV drivers' responses of a survey, the consensus was there is a parking shortage especially between 7 pm and 4 am, which is the reason for parking along traveling corridor ramps. Building more parking facilities and improving real-time driver parking information should be considered to reduce ramp parking.			
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1 EXECUTIVE SUMMARY

As commercial motor vehicles (CMV) traffic increases on roadways, CMV drivers are challenged with finding proper parking to comply with federal hours-of-service (HOS) requirements. Government agencies and private companies struggle to provide safe and reliable parking. While most drivers park in official parking facilities, many drivers still choose to illegally park along the shoulders of interstate entrance and exit ramps because of the inadequate CMV parking supply at both public and private facilities. By parking on these ramps, CMVs cannot fully utilize the ramps for proper acceleration and deceleration and are in danger of being struck by erratic vehicles. To date, state agencies (e.g., Department of Safety and Department of Transportation) have aimed to balance enforcement of parking policy, design, and safe operation of the state highway system.

State agencies recognize the inadequacy of CMV parking and are attempting to find solutions that meet the needs of increased CMV traffic, balancing both public and private objectives. This work starts by reviewing truck parking policy and strategies that can address parking shortage to understand the challenges with perceived or actual truck parking shortages on Tennessee's highway system, this research conducts an inventory of designated truck parking supply (both private and public sector) and parking demand at those facilities and along freeway interchanges. The scope of this work includes assessing all non-urban interstate facilities and interchanges (i.e., I-24, I-40, I-65, I-75, I-81). To assess parking, we visited each parking facility and rural interchange in Tennessee at least one time between the hours of 12:00am and 5:00am during a typical weekday in 2016. During that visit, we counted the number of occupied and unoccupied parking spaces, as well as CMVs parked outside of designated parking spaces. We also counted the number of CMVs parked on each ramp of interchanges. We present factors that are associated with truck parking on ramps and present the results of a short parking survey of truck drivers.

The results are remarkable. Statewide, formal truck parking facilities are 90% full. The entire I-24 corridor (~185 miles) is has more parking volume than supply; a well-intended driver could drive for three hours without finding a legal (non-urban) parking space. Still, less than 10% (75) of trucks on this corridor were parked on ramps. Statewide, our inventory revealed more than 300 trucks parked on ramps, two-thirds of which on on-ramps. Nearly 5,700 trucks were parked in official parking facilities, even if they were not all parked in designated spaces. Ramp features that were positively correlated with ramp parking include diamond interchanges, wide shoulders, long ramps, and "No Parking" signage. Wider lanes and two-lane ramps were correlated with less ramp parking.

Of our survey respondents, three quarters intended to park at a public or private rest area when they slept that night. Only 1% of respondents planned on parking on a ramp. However, if formal parking is full, more than half of respondents will continue driving. About 30% would park on a ramp. Ramp parking is the next alternative after continuing driving. Neither alternatives improve safety.

Better parking information is important and can provide marginal benefits, but Tennessee's highways suffer from persistent shortages of legal parking. Tennessee needs more parking on key corridors. In-sufficient parking for growing CMV fleets can be solved by more capacity and improved information. This study is among the first that explores statewide (Tennessee) parking supply and demand and aims to identify factors that influence illegal ramp parking.

2 INTRODUCTION

Public agencies struggle to provide adequate parking for commercial motor vehicles (CMVs) due to increasing truck traffic and static revenue. Therefore, CMV drivers must rely on private facilities to obey federal hours-of-service (HOS) regulations that require rest and are regularly diverted because of insufficient parking capacity at either public or private parking facilities. Drivers nearing the end of their duty with over-capacity parking face with two options: surpass HOS regulations to find legal parking, or park illegally on interstate on- and off-ramps. Many state agencies have recognized in-sufficient parking for growing CMV fleets and are aiming at providing better information and infrastructure to improve parking utilization rates and allow for better parking planning for drivers. This study is among the first that explores statewide (Tennessee) parking supply and demand and aims to identify factors that influence illegal ramp parking. We rely on an inventory of parking supply and demand as well as spatial analysis of ramp parking and geometric or other features of ramp parking that are correlated with capacity challenges. We also report the results of a survey of CMV drivers that focuses on perceptions and behaviors.

3 LITERATURE REVIEW

3.1 Background Overview

It is nationally recognized that commercial motor vehicle operators frequently cannot find adequate, safe parking for rest purposes, and often choose to park on shoulders of roadway mainlines and ramps or other undesignated locations, increasing the risk of crashes and accelerating the deterioration of the pavement on shoulders (1). A National Cooperative Highway Research Program (NCHRP) study provided important background on some of the reasons leading to truck parking deficiencies in the national highway system. It stated that the promulgation of hours-of-service (HOS) rules, in 1937, was one of the first steps by the federal government to address issues related to driver fatigue by establishing limits on the number of hours that truck drivers may drive and may be on duty before being required to take a mandatory break. The study added that complying with these rules, plus the substantial increase in truck traffic after deregulation of the trucking industry in the early 1980's and the "just-in-time" tightly scheduled delivery process are the primary reason for the increased demand for truck parking and a shortage of truck parking spaces in some parts of the United States. The NCHRP study (2) also reminded us that as originally conceived, public rest areas were designed to provide temporary rest locations for the traveling public. As the motor carrier industry has expanded, however, many public rest areas serve as long-term parking locations for long-haul commercial drivers, resulting in significant overcrowding. Public rest areas were never meant to compete with the commercial vehicle parking industry.

The literature presents a number of studies documenting shortages of public truck parking facilities dating back more than two decades. For example, in 1996, a study (3) on a nationwide inventory of public rest areas was developed, as well as mathematical models that pointed to a shortfall of 28,400 truck parking spaces in public rest areas. The research also assessed supply and demand for parking on private truck stops and results pointed to truck stop operators planning to expand capacity by 28,000 truck parking spaces. Additional analysis found no conclusive evidence that private truck stops and public rest areas are direct substitutes for each other, rather they are complementary. A Minnesota study (4) estimated that more than 50% of the public rest areas surveyed had a potential for nighttime capacity problems. A Tennessee

study (5) in 1999 indicated that more than 40% of truck parking on weekday evenings occurred on ramps and shoulders. In 2002, a national survey of truck parking spaces (6) identified 31,249 spaces at 1,771 public facilities (e.g., public rest areas, pull-offs, and weigh stations) and between 167,881 and 284,601 spaces at 3,382 commercial facilities. The demand model estimated a total demand for 66,067 spaces at public facilities and 221,249 spaces at commercial facilities. While the estimated demand for parking spaces at public facilities far outstrips the supply, the supply at commercial facilities seems sufficient to meet the current demand at the time. Recently, in 2015, the Jason's Law study (7) on truck parking reported that truck parking shortages are a national safety concern. Key findings pointed to thirty States observing shortages in public rest areas while sixteen States observed shortages in private truck stops. The Southeast was mentioned as one of the regions where drivers and logistics personnel reported most challenges with parking shortages. Furthermore, almost half of the State DOTs reported unofficial and/or illegal parking on freeway interchange ramps and shoulders of highways, with the State motor carrier safety officials corroborating the position.

In 2014, large trucks accounted for 11% percent of all traffic fatalities, with 61% occurring in rural areas and 79% occurring on weekdays (8). These fatalities are caused by truck driver fatigue, training, licensing, and drug or alcohol impairment and vehicle braking systems, maintenance, and lack of inspections (9). Several studies show that driver fatigue is the main reason for many truck crashes. A 1990 National Highway Traffic Safety Administration (NHTSA) study found that 31% of fatal truck crashes were due to fatigue. The duration of the last sleep period, the time slept in the past 24 hours, and the split sleep periods were the most important factors in predicting a fatigue related crashes (10). However, a more recent study found that only 8% of all fatal truck crashes were caused by driver fatigue (11). Fatigued CMV drivers are often left with the choice of parking illegally along highway entrance and exit ramps or to continue driving while fatigued or park illegally (5). Fatigue-related crashes motivate regulation mandating rest (i.e., HOS regulations). Even though there are set HOS regulations, drivers frequently surpassed the regulations (12). Tight delivery schedules are thought to drive most HOS violations (13) and that at least 26% of truck drivers would drive above the speed limit or violate HOS to ensure an on-time delivery (14).

In 2012, the Federal Highway Administration conducted a study (15) that highlighted considerations related to complexities involving commercial vehicle parking shortage. First, it pointed to an inadequate supply of truck parking spaces resulting in two negative consequences: tired truck drivers may continue to drive because they have difficulty finding a place to park for rest, and truck drivers may choose to park at unsafe locations, such as the shoulder of the road and exit ramps, if they are unable to find available parking (6). It warned that programs meant to address the problems of an inadequate supply of truck parking spaces must concentrate on a number of issues beyond simply providing additional parking spaces. For example, it may not be necessary for a federal program to earmark funds for States that already have sufficient supply of truck parking. Also, building spaces that have neither the convenience nor the amenities to convince a truck driver to use the space would not be helpful because tired truck drivers would either continue to drive to locate spaces with preferred amenities or would park in unsafe locations because of the greater convenience. Furthermore, parking spaces need to be adequately spaced so that a surplus of spaces is not developed in a select group of locations while other roadway segments continue to have an inadequate supply of spaces. The study also mentioned that opponents have argued that expanding public parking for commercial vehicles amounts to a subsidy of the trucking industry and unfairly penalizes the commercial truck stops that serve it.

A Federal Motor Carrier Administration (FMCSA) study investigated further the perspectives of truck drivers. The majority of drivers favored truck stops for overnight rest. The FMCSA survey asked respondents to speculate on why truck drivers sometimes choose to park on ramps and shoulders. Given reasons include the following (16):

- No empty spaces at nearby truck stops or rest areas (94%)
- No nearby parking facility is available (83%)
- Nearby parking spaces have time limits that are too short (approximately 50%)
- Nearby spaces were blocked by other vehicles (approximately 50%)
- The convenience of the ramp/shoulder for alighting onto the roadway (approximately 33%)
- Interruptions by strangers (drug dealers, prostitutes, etc.) were less likely (approximately 33%)
- Difficult to drive congested parking lots (18%)
- Ramps/shoulders have better lighting than the lots (4%)

Assessment of Federal and Tennessee-Specific Truck Parking Policies Moving Ahead for Progress in the 21st Century Act (MAP-21) Policies

The following summarizes the freight policy and truck parking policy included in the Moving Ahead for Progress in the 21st Century Act (MAP-21), a law that became effective in October of 2012 (17).

§1115 National Freight Policy

Section 1115 of MAP-21 establishes a policy to improve the condition and performance of the national freight network to ensure it provides the foundation for the United States to compete in the global economy. Some of the goals include investment in infrastructure and implementation of operational improvements with focus on reducing congestion, using advanced technology, improving safety, security, and resilience of the freight transportation and reducing environmental impacts.

§1401 Jason's Law

The purpose of Section 1401 of MAP-21, more popularly known as "Jason's Law," is to address the commercial motor vehicle parking shortage at public and private facilities along the National Highway System (NHS). Jason's Law directs the U.S. Department of Transportation (DOT) to conduct a survey and a comparative assessment to:

1. Evaluate the capability of each State to provide adequate parking and rest facilities for commercial motor vehicles engaged in interstate transportation;
2. Assess the volume of commercial motor vehicle traffic in each State; and
3. Develop a system of metrics to measure the adequacy of commercial motor vehicle parking facilities in each State.

3.2 Code of Federal Regulations

The following summarizes hours of service for CMV drivers, parking policies for hazardous materials vehicles, and landscape and roadside development regulations as stated in the Code of Federal Regulations (CFR) (18).

Hours of Service (HOS) Regulations

CFR Title 49 – Transportation - Part 395 regulates HOS restrictions for truck drivers. The following regulations are pertinent to commercial property-carrying drivers:

- Start of work shift - A driver may not drive without first taking 10 consecutive hours off duty.
- 14-hour period - A driver may drive only during a period of 14 consecutive hours. A driver may not drive after the end of the 14 consecutive-hour period without first taking 10 consecutive hours off duty.
- Driving time - A driver may drive a total of 11 hours during the 14-hour period.

There are additional detailed regulations of rest breaks, limit of number of hours on-duty and sleeper berth provisions.

Transportation of Hazardous Materials, Parking Rules

CFR Title 49 – Transportation - Part 397 regulates parking for trucks hauling hazardous materials. A motor vehicle which contains materials deemed hazardous must not be parked:

- On or within 5 feet of the traveled portion of a public street or highway;
- On private property (including premises of fueling or eating facility) without the knowledge and consent of the person who is in charge of the property and who is aware of the nature of the hazardous materials the vehicle contains; or
- Within 300 feet of a bridge, tunnel, dwelling, or place where people work, congregate, or assemble, except for brief periods when the necessities of operation require the vehicle to be parked and make it impracticable to park the vehicle in any other place.

Landscape and Roadside Development Regulations

CFR Title 23 – Highways - Part 752 furnish guidelines and prescribe policies regarding safety rest areas. It defines safety rest areas as a roadside facility safely removed from the traveled way with parking and such facilities for the motorist deemed necessary for his rest, relaxation, comfort, and information needs. It also mentions that the State may permit the placement of vending machines in existing or new safety rest areas located on the rights-of-way of the Interstate system for the purpose of dispensing such food, drink, or other articles as the State determines are appropriate and desirable, except that the dispensing by any means, of petroleum products or motor vehicle replacement parts shall not be allowed.

3.3 State of Tennessee Regulations

The following CMV parking policies are mandated by the State of Tennessee:

Tennessee Code Annotated (TCA)

Title 55, Chapter 8, Section 160- Stopping, standing or parking prohibits parking upon the paved or unpaved portions of any entrance or exit ramp of any highway, except when vehicle is disabled(19).

Tennessee Comprehensive Driver License Manual
Section B-4- It is illegal to park on the paved and unpaved portions of the entrance and exit ramps of the interstate highway, except when the vehicle is disabled (20).

Tennessee Department of Transportation (TDOT)
Maintenance Division of Welcome Centers and Rest Areas- determines that no overnight parking is allowed in these locations and that there is a two-hour parking limit as well (21).

Review of National Truck Parking Studies

In 1996, the FHWA (3) evaluated the adequacy of places for truck drivers to stop and rest. The research documented important distinctions between public rest areas and private rest stops. First, the differences in services provided apparently contributed significantly to truck driver's decisions about where to stop and for how long. For short-term parking, a majority of the sampled drivers expressed a preference for public rest areas while two-thirds of them indicated a preference for private truck stops for overnight or long-term rest needs. The study also examined options to increase truck parking at rest areas (TABLE 1).

TABLE 1 Options to increase CMV parking at rest areas (3)

Options for Increased Truck Parking at Rest Areas		
Options	Advantages	Disadvantages
CATEGORY 1 - MODIFICATION		
Option 1a: Use some car parking area for trucks at night	- Low cost - Increases truck parking during peak usage time	- Provides only a few parallel spaces for trucks during nighttime hours - Trucks may still tend to park on shoulders and ramps
Option 1b: Use existing park-and-ride facilities for night overflow parking	- Low costs for signing and publicity to drivers only - Provides parking for periods of high parking volumes - Space for pullthrough-type parking	- Does not provide normal rest area facilities - May require some enforcement to ensure that trucks leave before normal daytime use of lot begins - May only be feasible in select urban areas
CATEGORY 2 - RENOVATION		
Option 2a: Minor renovation of rest area parking lot with pull-through type spaces	- Maximum use of existing land - Provides parking for an additional number of trucks - Truck parking is pullthrough-type, allowing better utilization	- Moderate capital expense - Requires rest area (or sections of the rest area) to be temporarily closed - May not provide adequate additional parking for all trucks
Option 2b: Major renovation, convert/redesign existing parking lot to add additional truck parking spaces that are pull-through type.	- Maximum use of existing land - Provides potentially substantial additional parking for trucks - Truck parking is pullthrough-type, which has higher parking utilization than parallel	- May require extensive capital expense - Requires rest area (or section of the rest area) to be temporarily closed - Extra land may be required - May not be feasible at all rest areas
CATEGORY 3 - NEW CONSTRUCTION		
Option 3a: Build pulloff areas within the existing right-of-way with no additional facilities	- Supplies additional parking for trucks without cost of a complete rest area - Can provide day time picnic area for cars	- Moderate capital cost - If not visible from the Interstate, drivers may perceive that it is not safe for parking - May be rejected as a safety hazard - May lack public support
Option 3b: Build new rest areas	- Supplies maximum truck parking - Supplies security and service	- May require large capital expense - May require new land - Requires acceleration lane for re-entry - May lack public support

In 1999, the Federal Highway Administration (FHWA) Office of Motor Carrier and Highway Safety (OMCHS) hosted a Rest Area Forum to discuss the availability and safety of parking for commercial vehicles along the Nation’s highways (13). More than 70 State DOTs and enforcement officials, representatives of the motor carrier industry, private truck stop operators, commercial drivers, safety advocates, and other interested parties attend the forum. Some of the recommendations for the highest rated issues include:

Improve Safety and Security

- Placing law enforcement substations at public rest areas and increasing police patrols at both public rest areas and privately-owned truck stops.
- Promote a standard rating system for privately owned truck stops to help drivers determine if a facility is safe and secure.
- Redesign landscaping and lighting at public rest areas.
- Develop a faster and efficient method for drivers to report crime and still maintain

delivery deadlines.

Support Privately Owned Truck Stops

- Provide low-interest loans, public/private partnerships, tax incentives, and signage on highways.
- Support efforts to address public resistance to truck stops/rest area expansion and construction.

Use Alternative Parking Sites

- Use park-and-ride lots, State fairgrounds, stadiums, farmer's markets, and receiving and shipping facilities.

Improve Provision/Location of Public Rest Areas and Privately-Owned Truck Stops

- Adopt uniform spacing standards between parking areas (1-hour driving time).
- Encourage shippers and receivers to provide parking, especially in urban areas.
- Reopen closed public rest areas.
- Provide additional parking at existing facilities.

Improve Financial Support

- Raise the priority level of public rest area construction, modernization, and expansion by making rest areas a safety-related issue.
- Allow States to use Federal funds for public rest area maintenance.
- Explore the use of Federal, State, and local discretionary funds to support public rest area construction, modification, and maintenance.

Eliminate and Enforce Time Limits

- Eliminate time limits that specify less than 8 hours for legally parked commercial motor vehicles at public rest area.
- Enforce time limits, as space turnover is needed to accommodate the number of users.

Increase Driver Education and Information

- Target results of fatigue studies to receivers, shippers, carriers, insurance companies, and drivers.
- Provide drivers with standard information about the location and availability of public rest areas and privately-owned truck stops (via State maps, pamphlets, radio channel, etc.)

In 2000, a report (9) from the National Transportation Safety Board (NTSB) on truck parking areas found that parking adequacy, information and availability as primary challenges for truck parking. It also concluded that shippers, brokers, and consignees frequently influence truck schedules and should be an integral part of any solution to the truck parking area dilemma. Moreover, it added that The Federal and State governments have the responsibility to maintain highway safety and that the lack of available truck parking or the truck drivers not knowing where parking would be available can negatively impact safety. It continued saying that the prohibition against private development of rest area facilities on interstates may be an impediment to the construction of adequate truck parking. The study particularly recommended to several Governors, including the State of Tennessee that once the State has ensured that adequate parking is available, to eliminate or modify the time limits at public rest areas that can prevent truck drivers from obtaining adequate rest or redirect drivers to nearby parking facilities where they can obtain adequate rest. The effects of imposing time limits for truck parking on

public rest areas was studied and the policy pointed to the potential of drivers being discouraged from using these facilities for napping or sleeping. In addition, the time limits for drivers to park could substantially reduce the amount of needed sleep that drivers receive. NTSB acknowledged that time limits can help increase the availability of short-term parking but suggested posting signs in these areas that indicate where long-term parking would be available as a measure to help resolve these parking and time limit problems. Finally, the study discussed the hazards associated with parking on road shoulders of entrance and exit ramps and at highway interchanges. This practice limits the acceleration rate of the drivers who are parked on the exit ramp shoulder, creating the possibility that their trucks' speed may be significantly lower than that of the traffic on the main roadway. In addition, it creates a dangerous dilemma between high-speed vehicles decelerating into or accelerating out of the public rest area and lastly, shoulders are not protected from errant vehicles.

In 2002, a study (6) from FHWA documented findings of the adequacy of commercial truck parking facilities serving the National Highway System (NHS) in response to Section 4027 of the Transportation Equity Act for the 21st Century (TEA-21). This study was a follow-up to the 1996 study (3) conducted by FHWA, and two sets of recommendations were provided. First, the State partnerships proposed actions in six categories.

Actions to expand or improve public rest areas

- Construct new public rest area facilities with additional truck parking spaces.
- Consider developing truck-only parking facilities. Raise the priority of public rest area construction by making it a safety related issue.
- Add new truck spaces to existing public rest areas as part of scheduled rest area reconstruction or rehabilitation. Redesign and reconfigure rest areas to increase parking and improve commercial vehicle circulation through the lot. Also, convert parallel parking to pull-through parking for added driver convenience.
- Convert closed public rest areas into parking facilities and consider designating these facilities for truck-only parking.
- Investigate the use of Federal funds for maintaining public rest areas. Explore alternative financing of public rest area construction. Develop pilot projects for generating revenue to keep public rest areas open.
- Partner with other State agencies, such as the Department of Tourism, to incorporate truck parking needs into the development of new tourist information sites.
- Review and expand security at public rest areas by providing call boxes, cameras, increased law enforcement, etc.
- Identify locations where commercial vehicle parking can be combined with ports of entry, weigh stations, or police substations. Consider exempting trucks from enforcement actions to encourage the use of these sites for parking by fatigued drivers.
- Construct turnouts in rural sections of Interstate for parallel parking by commercial trucks.
- Upgrade facilities currently closed during off-season to be open year-round.
- Improve geometric design at interchanges to increase convenience to drivers choosing to exit. For example, increase turning radii, widen narrow bridges, place traffic signals where warranted, and add turning lanes to ease access and egress to commercial truck stops and travel plazas.

Actions to encourage the formation of public-private partnerships

- Create working groups between public and private sectors to develop new parking and explore options to overcome barriers to cooperation.
- Work with the private sector to redevelop or construct new public rest areas with direct access to the Interstate.
- Provide low-interest loans or grants to commercial truck stops and travel plazas to increase capacity.
- Construct State-owned lots adjacent to commercial truck stops and travel plazas and enter into agreements to lease or maintain the lots.
- Work with owners of commercial truck stops to help them promote the availability of parking in large lots close to the Interstate highway (e.g., provide signage on the highway).

Actions to educate or inform drivers about available spaces

- Educate drivers on the safety benefits of rest and encourage them to use available spaces. For example, provide safety information (e.g., through brochures and public service announcements) to both drivers and trucking companies about the relationship between driver fatigue and accidents to encourage fatigued drivers to get off the road.
- Develop ITS deployments that provide drivers with real-time information on the location and availability of parking spaces. For example, investigate using cellular phones and radio frequencies to broadcast parking locations and availability to drivers.
- Investigate using mailings related to credentials administration for the International Registration Plan (IRP) and the International Fuel Tax Agreement (IFTA) as a means of distributing information on the location and type of parking spaces within the base State to participating motor carriers.
- Publish and distribute a “trucker’s map” that pinpoints parking facilities for drivers.
- Initiate a program that informs drivers of State -approved parking facilities. Such facilities may have security, lighting, and other services that will encourage drivers to use existing spaces.
- Use both static and real-time signage to provide drivers with information about availability and location of public and private parking spaces.

Actions to change parking enforcement rules

- Implement more stringent enforcement of parking rules to remove vehicles from unsafe locations such as interchange ramps.
- Change parking limits to permit trucks more time to park at public rest areas.
- Encourage local government and business support for constructing and operating commercial truck stop facilities in or near their community industrial and business parks (i.e., zoning). The “Not in My Backyard” syndrome has made it difficult to gain this local support, and this issue has become a major problem in the development of new commercial truck stops and public rest area facilities near the boundaries of larger cities.
- Encourage better recognition or credit and tax incentives for companies and terminal operators who provide “truck staging area” facilities for pickup and delivery activities with 24-hour access, parking, sanitation, and security. This could be promoted at both the State and national levels.

- Promote building requirements for future warehouse and delivery facilities to incorporate truck parking and staging facilities as part of their development/building permit process. Encourage public/private partnerships to fund or offset these increased costs. This could be promoted at both the State and local levels.

Less detailed information was provided for actions to expand or improve commercial truck stops and travel plazas and actions to conduct additional studies. The study also provided results of discussing truck parking space availability issues with stakeholders (other than State partnerships) and portrayed how it affects various interest groups. These groups represent the enforcement community, the motor carrier industry, commercial truck stop operators, shippers and receivers, and the safety community. The following summarizes noteworthy recommendations:

- Use of existing facilities, such as weigh stations and park-and-ride lots, for parking, where possible – *America’s Road Team (ART)*
- DOT should explore technology for improving the efficiency of existing resources – *American Trucking Association (ATA)*
- A Federal mandate and funding for building new or additional parking facilities would be the most effective means of addressing the problem. Change State policies that restrict the amount of time truckers may stay in public rest areas. Use satellite parking to provide additional parking spaces. Communicate information on space availability and facility locations to drivers through variable message signs. – *Commercial Vehicle Safety Alliance (CVSA)*
- Implement a program that allows States to close rest areas in locations that are well served by private-sector businesses and shift funds to areas in which additional development is desirable. Remove cost-prohibitive road improvement requirements imposed by State DOTs upon developers attempting to open new facilities. – *America’s Travel Plazas and Truck Stops Association (NATSO)*
- Provide designated “trucks only” public rest areas. Stop closing existing public rest areas. *Owner-Operator Independent Driver Association (OOIDA)*
- Provide low-interest loans for developing truck parking facilities (absent direct funding or as a supplement). Explore public-private partnerships for developing additional rest facilities. *Parents Against Tired Truckers (PATT)*
- Set schedules so that drivers do not necessarily arrive in congested areas during peak times would help reduce overcrowding in some locations. The trucking industry could develop consortia to locate available parking areas in which inadequate parking currently exists, and large carriers could seek out parking areas within reasonable distances of thruways and contract for parking at those facilities. Trucking companies could also work with their customers, shippers, and receivers to allow trucks to park at their facilities. *Petroleum Marketers Association of America (PMAA)*

In 2003, a report (2) from NCHRP provided practices that have been used to manage the increasing demand for truck parking. Survey respondents were asked to rank the effectiveness and feasibility of a selected number of alternative strategies to address commercial vehicle parking demand. A measure was created that combined the effectiveness score and the feasibility score to determine what strategies respondents believed would be most feasible and effective to

implement. Results indicated the following strategies:

- Use Intelligent Transportation Systems (ITS) to expand amount of information available to truckers
- Expand existing rest areas for truck parking by providing more truck spaces
- Permit the use of weigh stations for parking
- Establish federal assistance program targeted at truck parking
- Encourage the development of public-private partnerships
- Build new rest areas for autos, trucks and RVs
- Permit the use of federal-aid funds to maintain public rest areas
- Build new rest areas for trucks only

Although NCHRP Synthesis 317 (2) indicated a favorable view of ITS, a report from the State of Connecticut (22) concluded that ITS would not be effective at reducing overcrowded parking at public rest areas in that State. The major concern expressed in the Connecticut report was that by the time the truck driver reached the rest area, the parking availability information would be out-of-date and incorrect.

In 2005, a report (16) from US DOT, Volpe National Transportation Systems Center provided information related to ITS and truck parking proposing strategies to reduce truck parking shortage. Recommendations fell into three major areas: a) making underutilized spaces more attractive, b) increasing the supply of spaces, and c) better matching supply and demand. Examples of making underutilized spaces more attractive include better lighting to reduce crime and improvements to parking layouts. Examples of increasing the supply of spaces include construction, using weigh stations and park and ride lots, and relaxing time limits. The most practical and cost effective of the three approaches is to start with the better matching of existing supply and demand in an area where a parking shortage exists. The study pointed to the availability of planning tools and real-time tools as examples of technology-based strategies to help truck drivers. It elaborated on two ways to make the driver's planning process more effective, using historical occupancy data and incorporating the process for rest stop selection into the same process that some carriers and drivers use to select refueling stops. At the time of the study several directories have been developed, both by private industry and government, to aid the planning process. None were comprehensive. Nevertheless, the available information could be enhanced by also informing the driver which stops are likely to have parking spaces available, given an arrival time and date. The study proposed that the design of the parking information system must be consistent with the National ITS Architecture, in particular those parts of the Parking Facility Management Package (ATMS16). Finally, the report pointed to the need of understanding that the impact of technology to improve utilization is neutralized when parking supply is severely inadequate.

3.4 Review of State Truck Parking Studies

In 2005, a study (23) by Washington State Department of Transportation (WSDOT) evaluated the adequacy of truck parking along Washington State's primary freight corridors and identified several strategies to increase truck parking capacity at public rest areas and commercial truck stops. Some of the strategies are listed:

- Reconfigure public rest areas to add truck parking capacity – reduce the facility's recreational vehicle and personal parking spaces to accommodate more truck parking, or

expansion of the truck parking into areas currently used for picnicking and other activities.

- Construct new limited-feature truck facilities (no picnic areas but including restroom facilities).
- Allow cross-utilization of the general public parking lot during nighttime hours.
- Legalize truck parking at non-Port of Entry weigh stations and expand these facilities to accommodate additional parking.
- Provide free signage along interstate highways for existing commercial truck stops in exchange for truck parking and other qualifying criteria (such as 24-hour service).
- Lease WSDOT right-of-way/property at low rates to provide commercial truck stops services and amenities. This option would encourage commercial development based on low lease rates and proximate location to the mainline. Services and amenities typically offered at existing commercial truck stops would be mandatory, and additional truck parking support facilities could also be required.
- Provide low-interest loans for new development. Services and amenities typically offered at existing commercial truck stops (e.g., truck parking, fuel, electrification, showers, food/convenience store) would be required. Loans could be used for any costs related to property acquisition, construction of the facility, or other business start-up related costs.
- Subsidize operational costs. Operational costs for existing commercial truck stops would be reduced in the form of grants and/or loans. This funding could also be restricted to a one-time opportunity or could be reapplied based on compliance with certain criteria. This option could be particularly relevant in urban areas where land value is typically higher, or where operational costs outweigh revenue.
- Provide low-interest loans for expansion-related costs. Although some commercial truck stops may generate sufficient revenue, the business lacks the initial cost to expand the facility, despite the available land and truck parking demand. Low-interest loans would fund acquisition of adjacent land to provide additional truck parking.
- Provide nighttime-only parking at commercial parking lots. This option would identify large commercial parking lots that are underutilized during nighttime hours in close proximity to the Interstate highway. Parking lots for consideration could include those belonging to malls, shopping centers, or other large commercial enterprises (e.g., movie theaters, large retail stores).
- Provide nighttime-only parking at public park-and-ride lots. Several public park and ride lots are underutilized during the nighttime hours and are located in close proximity to the Interstate highways. WSDOT would coordinate with local jurisdictions and transit agencies to enter into agreements for truck parking usage.
- Use Intelligent Transportation Systems solutions and produce and distribute a trucker's guide. This guide would contain the location, distance (mileage and time travel) from the mainline, and directions to every public rest area and commercial truck stop in Washington State. Other features, such as services and amenities, peak period, peak season, percent typically full, and other information could also be included.
- More clearly designate truck parking from recreational parking at all public rest areas.
- Coordinate with local and state patrol to enforce current truck parking laws by consistently citing truckers parked along roadsides, ramps, and other illegal areas.

In 2006, George Mason University's School of Public Policy (24) examined policies

regarding commercial truck parking in the Commonwealth of Virginia. The study expanded on recommendations identified in other studies and analyzed if seven different criteria would be met for each alternative presented (TABLE 2).

TABLE 2 Summary analysis on commercial truck parking alternatives (24)

Alternatives		Criteria						
		Consistent with Federal Policy	Economics & Costs	Technological Feasibility	Equitable	Enforceable	Safety	Community Impacts
No Action		No	Maybe	Yes	Maybe	Yes	No	Yes
Improvement of Existing Rest Areas	Re-Design & Layout of Rest Area	Yes	Yes	Yes	Yes	Maybe	Yes	No
	Demand Management	Dropped from Consideration						
	ITS	Yes	Yes	Maybe	Yes	Yes	Maybe	No
Utilization of Other Infrastructure	Use of Highway Access Ramps	Maybe	Yes	Yes	Yes	Yes	No	No
	Use of Weigh Stations	Yes	Yes	Yes	Yes	Yes	Yes	No
	Private-Public Partnerships	Yes	Maybe	Maybe	Yes	Yes	Yes	Yes
	Use of Large Parking Lots	Dropped from Consideration						
Expanding Capacity	New Rest Areas	Yes	No	Yes	Yes	Yes	Yes	Maybe
	Existing Rest Areas	Yes	Yes	Yes	Yes	Yes	Yes	Maybe

The study warned that the “no action” alternative would create larger problems to VDOT if truck usage continued to increase steadily in the future, similar to recent year’s trends. The main reason would be deterioration of existing rest area facilities (due to overcrowding) and deterioration of asphalt along entrance and exit ramps due to a predicted severe shortage in rest area availability. For the “expanding capacity” alternative the addition of new facilities was desirable on routes where distances between existing rest areas are far apart. For the “improvement of existing rest areas” alternative, it was recommended for VDOT to re-assigns

the numbers of parking spaces reserved for trucks and consider converting space designated for automobiles to trucks for the night time hours. In addition, it was also recommended for VDOT to redesign existing parallel truck parking space to a diagonal layout and to re-examine the 2-hour limit on truck parking. For the “utilization of other rest areas” alternative, especially regarding the use of highway access ramps, the study viewed interchange entrance ramps (inside shoulder, no sight distance restrictions) as an opportunity for short-term parking, however, the ramp shoulder would need to be widened and reinforced to accommodate parallel truck parking. To accommodate parking for tractor-trailers along interchange ramps, the interstate semitrailer with 53ft trailer should be considered. Using the semitrailer as a model, the design of the parking lane width should be a minimum of 16ft; however, where available, a wider parking lane should be considered. Shoulder parking areas will require the reinforcement of the shoulder with concrete, as tractor-trailers are big, heavy vehicles that cause damage to non-reinforced surfaces. Exit ramps were not viewed as an opportunity for short-term parking due to safety reasons. It was also recommended that section 111(a) of Title 23 of the US Code be revised, which prohibits commercial development at travel information centers or rest areas. This was considered a strong contender for revision as Congress has made exceptions in the past by passing specific exceptions to allow commercial use of the right-of-way. Finally, a recommendation was made to amend the regulation of 2-hour parking limit to meet the Federal rule of 8 hours of consecutive hours off duty after 10 hours of driving.

Also in 2006, a study (25) by the Baltimore Metropolitan Council emphasized public-private partnerships and local problem solving as two key strategies to address truck parking challenges. The first recognizes that there is significant potential for innovation and alternative truck parking locations by directly bringing various private sector actors into the process – including but not limited to economic development organizations, commercial realtors, and others. The second recognizes the extent to which the hands of involvement of communities are essential. Some of the recommendations of this study are:

- Advance a Public-Private Partnership (P3) initiative for regional truck parking.
- Explore tax incentives for private investment in truck parking and/or the provision of land for parking
- Advance a pilot/demonstration project with public and private partners
- Issue a Request for Information (RFI) as a means of inviting and testing market-based solutions to rest area parking needs. In the process, promote partnership approaches among developers, businesses, commercial real estate agents and others
- Advance a multi-state truck parking strategy with contiguous regions and corridor states
- Advance truck parking Intelligent Transportation Systems (ITS) initiatives
- Establish a basic performance monitoring and data collection protocol and process to regularly assess regional truck parking utilization
- Secure funding for various initiatives through federal and other sources
- Determine the feasibility of expanding existing facilities
- Incorporate truck parking improvements in project planning and design
- Encourage managed parking closer to industrial parks and other truck origins/destinations
- Identify “safe-haven” truck parking locations. This would allow law enforcement officials to direct illegally parked truck operators to designated parking locations to increase safety. As such, a safe haven initiative would have both law enforcement and parking capacity benefits.

In 2007, a study (26) from the Pennsylvania State Transportation Advisory Committee (TAC) provided an overview of the truck parking issues and trends facing Pennsylvania, the identification of regions in the state where parking demand is highest, and options for parking providers, drivers, and decision makers. The TAC recommended PennDOT to provide overall leadership to eliminate unsafe truck parking practices and to assist in facilitating new and expanded facilities as well as innovative ways to foster partnerships. A 12-point strategy was recommended as a comprehensive approach to meet truck parking needs (FIGURE 1).

PARTNERING	1. Advance TAC study recommendations by forming a public-private task force.
	2. Collaborate with neighboring states to forge regional solutions.
	3. Explore opportunities for expanding truck parking capacity and local economic development through dual-use facilities, brownfield re-use, and provision of parking at truck-oriented developments.
POLICY	4. Remove obstacles to public-private partnering for truck parking facilities and driver services.
	5. Develop a truck parking policy through the National Governor’s Association and the American Association of State Highway and Transportation Officials for the reauthorization of federal transportation legislation emphasizing partnership, innovative finance, and new funding programs.
PLANNING & FINANCE	6. Explore all funding opportunities, particularly for innovative pilot projects.
	7. Address truck parking through established statewide planning and programming processes.
	8. Reevaluate approaches for accommodating the growing truck parking demand on toll facilities, particularly the PA Turnpike mainline.
	9. Establish appropriate performance monitoring to track progress.
TECHNOLOGY & DESIGN	10. Develop complementary ITS applications that support more efficient operations and truck parking.
	11. Evaluate new truck parking design concepts to provide improved access to services, more parking at existing sites, and improved circulation.
	12. Integrate technologies and design principles into truck parking facilities to mitigate environmental impacts.

FIGURE 1 Pennsylvania 12-point strategy to meet truck parking needs

In 2008, the North New Jersey Transportation Planning Authority conducted a study (27) to outline the requirements, inventory, issues, and solutions to address the significant lack of truck parking spaces in the region. A survey was conducted with truck drivers and interestingly, the majority of the drivers surveyed identified that they preferred parking locations to be within 3 miles of the highway system. If the facility is more than 5 miles, patronage would significantly decline. Other common themes that were identified in the surveys of drivers and industry included that truck stops should be simple, safe, and clean and that there is little need for excessive amenities. The primary focus of the study was to identify potential sites for development or expansion to accommodate truck parking needs. Nevertheless, the study also pointed to policy and planning issues recommendations.

Policy / Institutional

- Secure sites as a necessary land use - Truck parking should be seen not as an undesirable use but as a requirement of regional logistics and its efficiency.
- Advance favorable federal legislation that promotes innovation and public-private partnerships - Issues requiring federal attention include providing a framework for multistate initiatives, loosening decades old restrictions on public vs. private facilities, encouraging private investment in truck parking capacity, ITS/technology, and new funding. Partnership and collaboration will provide an equitable approach to providing public benefit while maintaining private interests.
- Pursue alternative fuels, energy, and environmental opportunities – any efforts to make truck parking facilities as green as possible will be a key element of making these sites more amenable to their host communities and to future energy policy.
- Advance complementary land use approaches - Operations of nearby facilities should be considered in that a truck parking facility may enhance the value of nearby industrial operations by reducing the need for truck parking at each site and pooling it at one location. In addition, such a site may be used for preprocessing, inspection, and/or security clearance of truck freight.

Planning, Finance and Partnering

- Provide incentives for private sector development of truck parking - It is a fairly safe assumption that the private sector is the preferred developer, operator, and maintainer of truck parking facilities if the economics are achievable. Yet the public sector has a vested interest in this issue including the safety and capacity issues associated with truck parking. It is important to recognize that truck parking is a public good with public benefit but in the main private enterprise.
- Incorporate truck parking as a future design parameter for facility improvement planning and design - At any given point there are a number of highway improvements planned, designed, or being constructed throughout the region. Incorporating truck parking at the time other improvements are being completed is a cost-effective way of addressing the issue.
- Integrate truck parking as an element of port and intermodal facility development and growth planning - The essence of this issue area is to take steps to ensure that truck parking capacity keeps in pace with the overall growth of truck traffic in the region in the long-term.

- Collaborate on a broader scale with neighboring DOT's, MPO regions, and local planning officials - Freight movement and its related truck parking needs transcend state and municipal boundaries. To view this as an opportunity will benefit the region and its economic base. The accommodation of the needs of trucks and their drivers present prospective economic opportunities that should be viewed as potential benefits and not a nuisance.

3.5 Illegal Parking Safety Implications

Truck parking along interchange ramp shoulders is often the last option for CMV drivers. However, citations of truck parking are rarely issued causing more drivers to utilize these ramps (28). Various studies have recognized that parking illegally on the road shoulders of entrance and exit ramps at interstate interchanges is hazardous. Garber et al. found that the involvement ratio of trucks on ramps increase with the speed difference between the average speed of trucks approaching the ramps and posted speed limit (29). Vehicles may wander into the shoulder and hit parked vehicles. An example of this hazard occurred in June 1999 on Interstate 40 in Jackson, Tennessee when a truck was accelerating onto the interstate and hit a parked tank truck (30). Five occupants were fatally injured.

Agent and Pigman (31) examined large truck crashes in Kentucky involving various classifications of vehicles parked along the shoulders and found it entailed 1.8% of all crashes on the interstate; however, the percentage of fatal crashes is 11.1%. Approximately, 60% of the accidents were due to the other vehicle driver. Data from January 1990 to April 1996 was evaluated and an accident analysis determined that 0.3% of CMV accidents involved illegally parked vehicles on shoulders (28). Even though CMVs are large in size and more noticeable than other parked vehicles along the ramp, these are still hit in the rear by other vehicles. It was also found that drivers lack information on available parking when the capacity exceeds the supply.

4 METHODOLOGY/DATA ANALYSIS

4.1 Objective

By examining the inventory of existing legal parking utilization throughout the state along with assessing CMV drivers' perspective, relationships between ramp characteristics and ramp parking are evaluated. Data gathered for parking facility includes ownership (private versus public), parking occupancy, volume-to-capacity ratio (v/c), and utilization of parking stall (designated versus outside designated parking). As for the ramp characteristics, the following was analyzed to determine whether these correlated with the number of trucks parked along the ramp:

- Horizontal alignment
- Material of the ramp's shoulder
- Width of the ramp's shoulder
- Presence of no parking signs
- Number of lane(s) on the ramp
- Width of lane(s)
- Length of ramp
- Proximity to truck facilities
- Presence of lighting

4.2 Collection of Parking Data

Tennessee has three main north/south freeways and three main east/west freeway (FIGURE 2). Notably, in Tennessee, all parking on ramps is illegal. Utilization rates of illegal ramp parking as well as designated truck parking were recorded during peak hours (12 am to 5 am) of off-duty rest during the weekday (Tuesday morning to Friday morning), consistent with peak hours reported in the Federal Highway Administration’s report (7). Data collection spanned December to April, 2016. Occupancy rates were measured simply as presence of trucks at a given time during that period. We measured occupied parking spaces, unoccupied parking spaces, and vehicles parked outside of designated parking spaces at each parking facility. Parking supply was determined from a combination of Jason’s Law database and aerial imagery from Google Earth. All exits were investigated to count the available parking at the formal public and private truck parking locations. Estimates were corroborated with the visits to the facilities.



FIGURE 2 Tennessee’s interstate system

The recorded truck parking in legal parking facilities, public and private, and on ramps is presented in TABLE 3. Of note, we did not include off-freeway truck parking in informal parking facilities (e.g., shopping centers). The interstates were aggregated based on the highway corridor to yield a better representation of the data. As shown in the table, there is one corridor, I-75 north of Knoxville, that does not have written record of public parking facilities. Several facilities, all public, were overlooked during the data collection process and should be recorded in future research.

TABLE 3 Tennessee parking volumes during peak hours of off-duty

Highway Corridor	Approx. Length (miles)	Public Parking Facilities		Private Parking Facilities		Parked at Interchanges		Annual Average Daily Traffic (AADT)	
		Designated Spaces	Total Parked	Designated Spaces	Total Parked	Parked on off-ramps	Parked on on-ramps	Avg.	% Trucks
I-24 from KY to Chattanooga	185	90	91	594	686	32	43	80,662	24
I-26 from KY to NC	31	53	26	0	4	0	0	32,063	11
I-40 from AR to NC	455	150	152	3,125	2,864	35	75	61,102	29
I-65 from KY to AL	122	15	15	395	412	7	22	83,333	20
I-75 from GA to I-40/75 Junction	85	40	46	345	371	22	29	60,846	26
I-75 from Knoxville to KY	58	N/A	N/A	245	253	3	14	50,435	24
I-81 from Dandridge to VA	76	134	105	509	403	7	26	30,541	34
Total	1,012	482	435	5213	4993	106	209		

4.3 Collection of Ramp Characteristics

Ramps are crucial pieces of infrastructure that allow vehicles the proper distance to accelerate/decelerate into traffic. Interchanges have more crashes per mile than any other section of the interstates and yet, these locations are often used as overnight parking for CMV.

Numerous characteristics of approximately 895 rural ramps in Tennessee were recorded through Google Earth, Inc. and Tennessee Department of Transportation's (TDOT) Enhanced Tennessee Roadway Information Management System (E-TRIMS). Notably, this method might not display the current attributes of the ramps and it yields approximate values of the various features. These characteristics were analyzed to determine the effects on truck parking. It should be noted that eight of the ramps were in construction in the aerial photograph and the attributes could not be collected. None of these under-construction ramps had recorded overnight truck parking.

Google Maps allowed the collection of the geometric curve of the ramps, which were aggregated based on if it was straight (diamond interchange) or curved (trumpet and cloverleaf). The width and material of the ramp shoulders were collected through aerials photographs on Google Earth. Frequently, shoulders were stained with oil and these locations were used for data collection. When these indicators were unavailable, the shoulders with the greatest width were used. The material of the shoulders was group by asphalt, concrete, gravel, or mixed. Through

Google Maps Street View, the absence or presence of no parking signs and lighting on ramps were gathered. The lane width and the number of lanes of the ramp near the interstate and nearest intersection along with the length of the ramp were taken into consideration. The Network Analysts Tool in the geoprocessing software, ArcGIS, allowed the proximity of the nearest recorded truck facility from the ramps to be determined. E-TRIMS output the annual average daily traffic (AADT) and percentage of trucks along the five freeways.

We expect that CMV drivers will prefer to park on lengthy off-ramps that are absent from geometric curves. Drivers are expected to park on paved shoulders with wide lanes and proximate to truck stops.

4.4 Collection of CMV Drivers' Perspective on Parking

The development of a survey was used to investigate CMV drivers' perceptions on parking, focusing on long-haul drivers. The survey was a comprehensive instrument that contained many categories of questions including intelligent transportation system (ITS) technologies, which created consistency and allowed comparisons with previous large-scale CMV driver surveys (2) (9) (6). The comprehensive instrument required approximately 15 to 20 minutes to complete and resulted in a relatively low sampling size (N=167). A less-comprehensive short-form survey was also administered of CMV drivers (N=333). Some of the questions and responses on the short-form survey correspond with the CMV drivers' perspective and will be used. The surveys were conducted by the research team when CMV drivers were fueling or waiting to fuel. This gave CMV drivers ample time to read and respond to the surveys. Most of the data were collected in the early morning (8 am-10 am) and late afternoon (4 pm-6 pm) during weekdays in 2012. The surveys include general questions about CMV transportation and the surveyors were careful not to lead the respondents that this study was aiming to answer specific questions about CMV parking, but rather generally gauging driver perceptions related to parking and technology.

The majority of the surveys were completed in Knoxville, Tennessee area at privately-owned truck facilities on the I-40/75 corridor due to this area because an intersection of two major long-haul corridors in the Southeast region of the United States (32). This corridor consists of an average annual average daily traffic (AADT) of 149,072 vehicles with 15 percent being trucks. Additionally, a long-form survey was deployed in South Carolina, Georgia, Virginia, and Alabama at different sites to take representative data from different highways for the southeast region. The 167 survey responses were obtained with a response rate of 64%. The short-form survey, deployed only in Knoxville, had a response rate of 82%.

5 RESULTS AND FINDINGS

5.1 Parking Facilities

Public truck facilities are intended to meet the basic rest needs of CMV drivers where private facilities are market-driven and provide additional amenities. The public and private truck parking facilities along with their capacity, number of trucks parked in spaces, and number of trucks parked outside of spaces was analyzed. At numerous facilities, drivers would park outside of designated spaces even though there were spaces available (FIGURE 3). This is likely an indication that parking was full when the driver arrived but could also be because of difficult maneuvering in the facilities, easier accessibility to the interstate, not well marked parking spaces, and safer locations within the facilities. This figure illustrates Tennessee's volume-to-

capacity ratio of 94 recorded truck parking facilities in addition to saturation rates. Some interchanges include more than one parking facility and this figure combines those to provide a composite capacity. The average utilization rate of these facilities is 90% with a standard deviation of 30%. The rates ranged from a minimum of 0% at a fast food restaurant on Interstate 40 to a maximum of 187% at a truck stop on Interstate 24 (though the capacity of that facility was small). The number of trucks parking on ramps is indicated by the small pie charts in FIGURE 3 but is also highlighted in FIGURE 4 to identify areas with high volume of illegal ramp parking.

Interstate 40 spans over 400 miles and has the most parking facilities for CMV drivers. However, over three-fourths of its facilities are utilized at a rate of 75% or larger. It is evident that there is shortage of private and public parking locations for CMV on sections of Interstate 24, 65, and 75, which leads to drivers to parking on the corresponding exit's ramp. Interstate 24 has 16 parking facilities, 10 private and 6 public, and 15 of them reached or extended capacity. Interstate 26 has a smaller AADT and percent of traffic being trucks compared to the other interstates and was the only one with all facilities being undersaturated. There are many occurrences where facilities are oversaturated prior to a stretch of roadway with no parking facilities. One example is Interstate 81's exits 8 and 21 where exit 8 has 160% utilization and exit 21 has less than 10% used. Drivers are challenged on whether they should park outside of spaces if there is any area available, park along ramps, or keep driving another 13 miles. This decision leads to safety issues on illegal parking and drivers fighting fatigue.

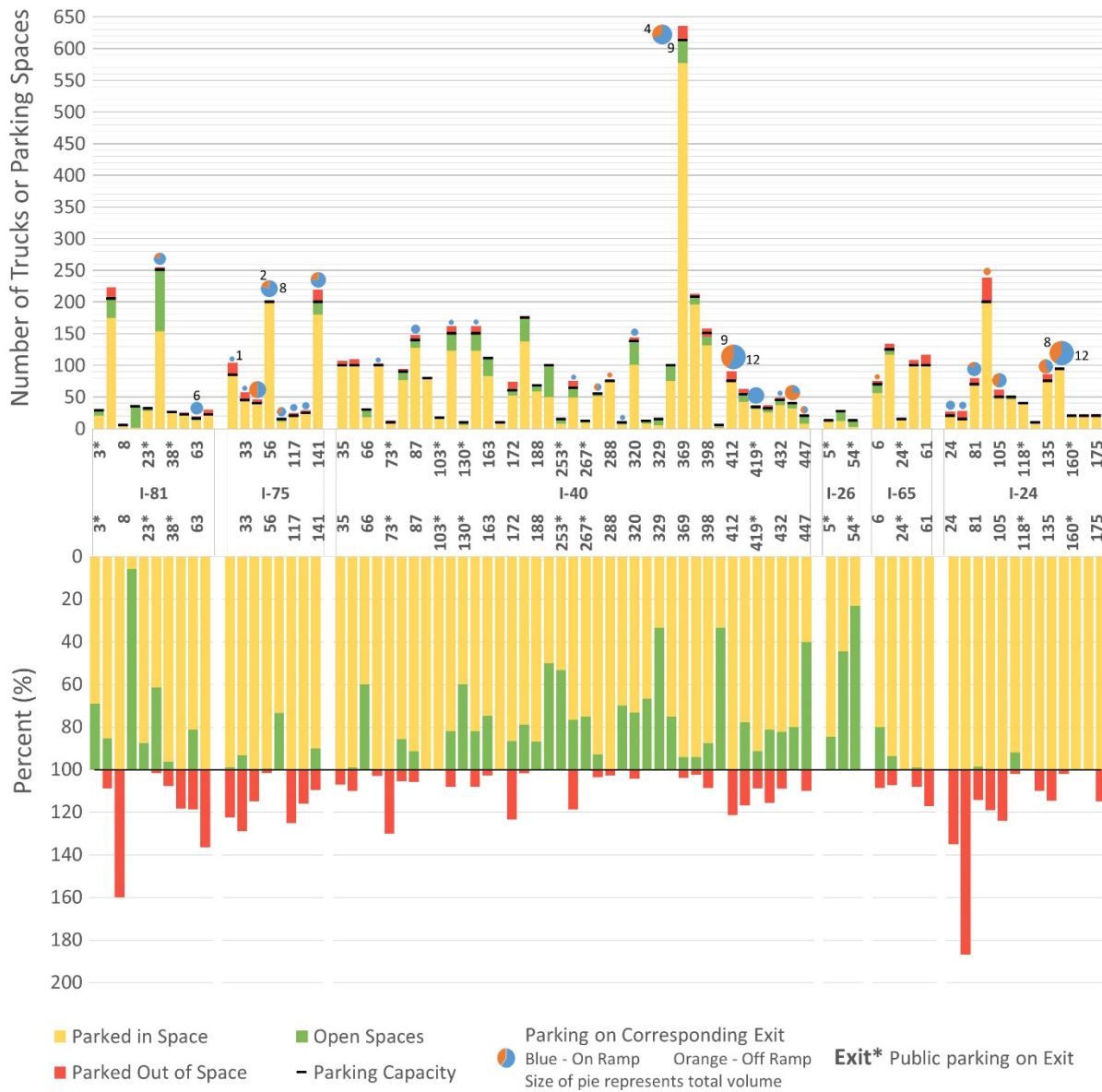


FIGURE 3 Utilization of public and private parking facilities

5.2 Ramp Characteristics

In many cases, there is limited parking availability in both private and public facilities and CMV drivers are faced with continuing driving, perhaps surpassing HOS, or utilize ramp shoulders. CMV drivers used 134 ramps along Tennessee’s interstate system for overnight parking (FIGURE 4). On average, each ramp contained 0.37 trucks with about half of the trucks that we observed parked alone on the ramp. The on-ramp was the preferred location, with 61.9% of trucks using the on-ramp, which had a t-test significance of 0.000. The majority (94.0%) of the trucks used the shoulders of ramps that were a type of a diamond interchange. A t-test of the geometric shape of the ramp yielded a p-value of 0.000, illustrating it is significant. Of all the ramps analyzed, 695 (81.4%) lacked a no parking on shoulder sign with 106 (79.1%) of these

ramps being utilized for over-night parking. This attribute also had a p-value of 0.000 illustrating its significance. The mean width of the shoulder was 15.5 feet (standard deviation 3.6 feet) while the average ramp width was 13.0 feet. Drivers utilized shoulders that had a mixture of pavement (65.6%), typically a combination of asphalt and gravel, compared to concrete, gravel, and asphalt. The most frequent shoulder material was mixed (60.4%), asphalt (37.5%), concrete (1.4%), and gravel (0.7%), respectively. All of the parking locations had only one lane entering or exiting the interstate system and 94% had one lane at the nearest intersection. In comparison, 840 ramps only had one lane exiting/entering the interstate and 725 ramps had one lane at the nearest intersection. The lane width of the interstate (t-test significance of 0.000) was normally distributed with an average of 15.4 feet, which is also the average of all the ramps. However, the intersection width of the utilized ramps was skewed right with an average width of 16.5 feet while the average of the population was 18.1 feet. The ramp length of parked trucks ranged from 589 to 3,300 feet with a mean of 1,327 feet similar to the mean of the 854 ramps examined. The average proximity to the nearest truck stop was valued at 6.5 miles (standard deviation 5.6 miles) for both the total population and ramps parked on. While 56.6% of ramps do not have lighting, 58.2% of CMV drivers chose locations without lighting.

The western region of Tennessee (i.e. I-40 between Memphis and Nashville) does not as much ramp parking as central and east Tennessee. Interstate 75 has the most acute CMV parking on ramps than any other interstate, especially between Chattanooga to the junction of I-40/75, were a total of 57 trucks parked along the 66-mile corridor. In addition, a northbound rest area had 5 trucks parked on both the entrance and exit ramps in addition to 40 trucks parked legally in spaces.

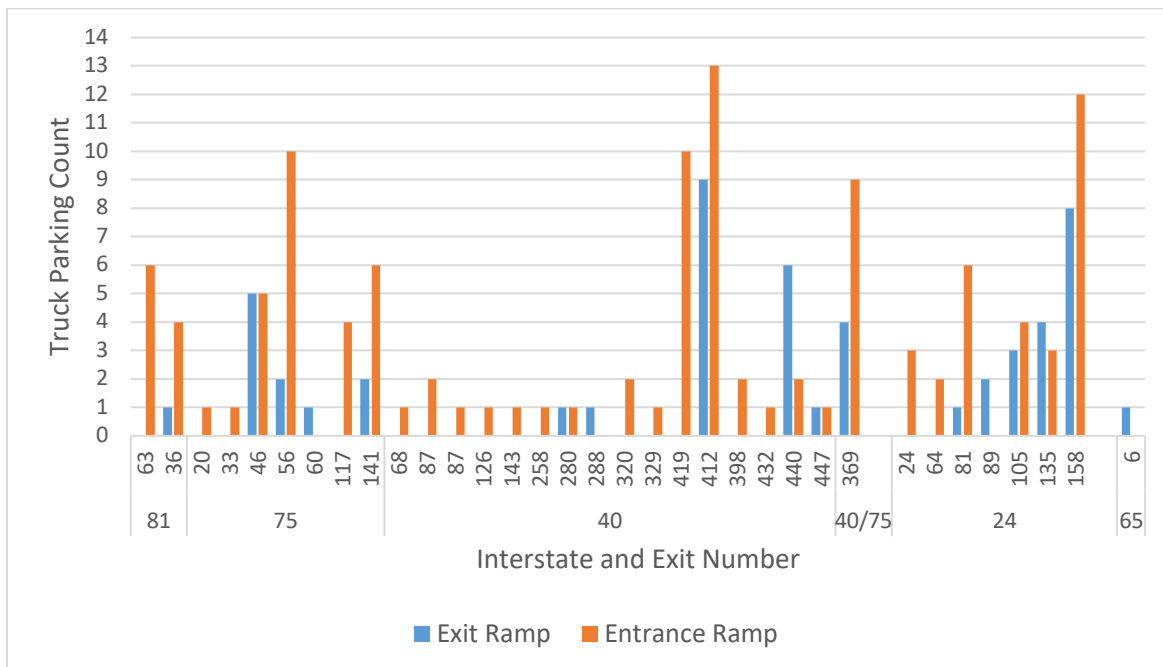


FIGURE 4 Utilization of ramps for CMV parking

5.3 Correlation of Truck Parking and Ramp Attributes

Pearson’s correlation coefficient allows the measurement of correlation between truck parking on ramps and various ramp factors. Pearson’s correlation is a measure of linear correlation between variables. For this study, ramp attributes were correlated to the number of trucks parked along the ramp (TABLE 4).

TABLE 4 Results of Pearson Correlation

Number of Parked Trucks on Ramps	Pearson Correlation	Significance (2-tailed)
Geometric Shape (diamond)	0.080	0.019
Shoulder Material (mixed)	0.044	0.200
Shoulder Width	0.192	0.000
No Parking Signage	0.112	0.001
Number of Lane(s)	-0.041	0.234
Exiting/Entering Interstate	-0.026	0.456
Width of Lane(s)	-0.086	0.012
Exiting/Entering Intersection	-0.093	0.006
Length of Ramp	0.068	0.048
Proximity	0.016	0.636
Lighting (absence)	-0.303	0.380

Sample size: 854

TABLE 4 illustrates a significant positive relationship between ramps that are diamond shape and the number of trucks parked on the ramp. The wider the shoulder the more area the truck has to securely park the vehicle, which can create a sense of safety to the driver. This attribute also has significant positive relationship with the dependent variable. It is logical that the absence of the signage increases the number of trucks parked, but signage can also be correlated with high demand areas. The smaller the number of lanes and width near the intersection, typically means less amount of traffic. These characteristics along with the length of ramp were significantly correlated with the ramp parking, which is an interesting finding due to numerous recorded trucks parking close to the intersection to allow more distance for acceleration onto the interstate.

5.4 Characteristics of Survey

The respondents of this survey were generally consistent with profiles of respondents from other studies (9) (12). The majority of the respondents in this survey were middle aged white males (TABLE 5). However, the age of the respondents varied from 21 to 72 with an average age of 47 years. Drivers were classified into three equal age groups to further analyze the relation of age with the needs and preferences of drivers regarding CMV parking issues. More than half of the drivers indicated that they drove for a large-sized carrier.

TABLE 5 Characteristics of survey respondents

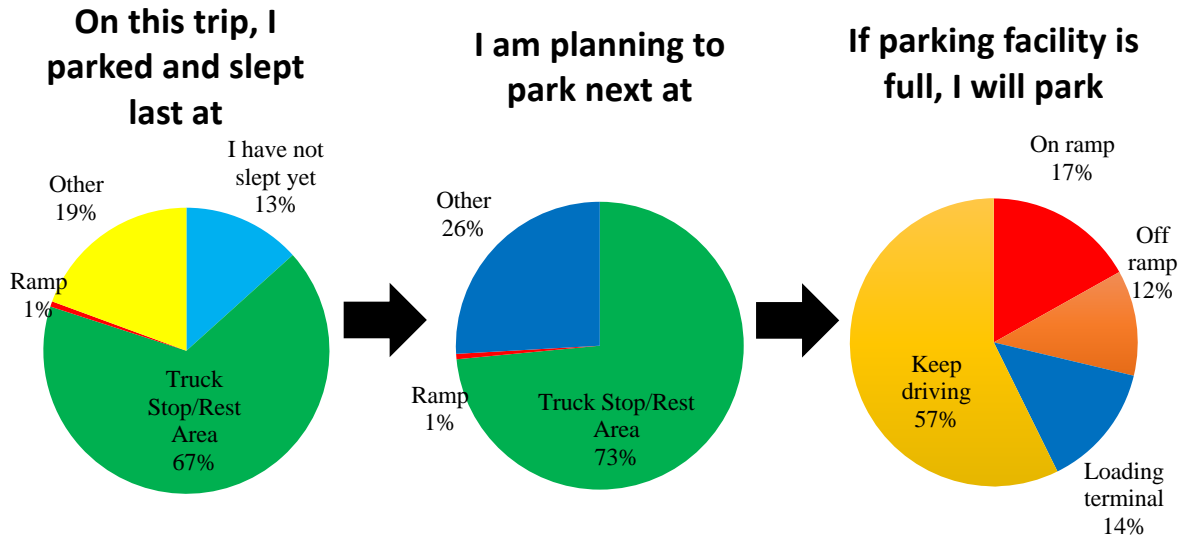
	N	%
Gender		
Male	471	95
Female	25	5
Age		
18 to 35	91	19
36 to 53	269	54
54 to 72	133	27
Race/Ethnicity		
White	333	69
Black	101	21
Other	48	10
Driver Category		
Owner/operator (1 power unit)	66	14
Owner/operator (multiple units)	14	3
Driver for owner/operator	18	4
Driver for a small-sized carrier	34	7
Driver for a mid-sized carrier	74	15
Driver for a large-sized carrier	270	56
Other	7	1

While the surveys were administered in the Southeast US, the results may be nationally representative. The participants were asked about their current trip and by using their trip origins and destinations, the estimated shortest path was generated. It resulted in all states except Hawaii being represented in the dataset as origin, destination, or pass-through. The majority of the routes traversed over the eastern portion of the US primarily due to sampling the southeast. CMV drivers traveling in northern and western region were not well represented in the sample, with less than 10% of the sample including a trip segment in those states.

5.5 CMV Driver Behavior

To determine whether the participants were a well representative of overnight CMV drivers, the drivers were asked the approximate number of days per month they slept away from home. The drivers responded with an average of 23 days each month they sleep away from home. The responses varied widely, ranging from 1 day to 31 days, with a standard deviation of 6.8 days, which is consistent with the driver responses in Chen et al (9). Follow-up questions were asked to determine the location of rest upon reaching their daily HOS. The questions were designed to study drivers' dilemma of whether they continue driving and violate HOS or park illegally.

Drivers were asked three different questions to assess CMV driver behavior towards parking: last parking location, planned parking location, and actions if there is unavailable parking (FIGURE 5). The majority (75%) of drivers stated that they keep driving if they cannot find a parking space leading to the potential of a HOS violation and/or fatigue, which is consistent with Braver et al. (12). Over one-third of the participants would park along the interstate entrance and exit ramps if planned parking was full, but just one respondent actually prearranged to park on a ramp. Some of the drivers responded that they know the safety risks of parking on a ramp but are forced to do so because of full truck facilities.



Note: The first two questions were not included on the abbreviated survey instrument.

FIGURE 5 CMV parking behavior

5.6 CMV Drivers Parking Needs and Preference

The respondents of the long-form survey were asked to rate various encountered parking problems on a 5-point Likert scale, where 1 indicates “never” and 5 indicates “always” (FIGURE 6). The mean of these five responses, 3, indicates a neutral response in the scale. Mean responses greater than 3 were defined as positive; whereas, mean responses less than 3 were defined as negative. Non-responses are listed as N/A.

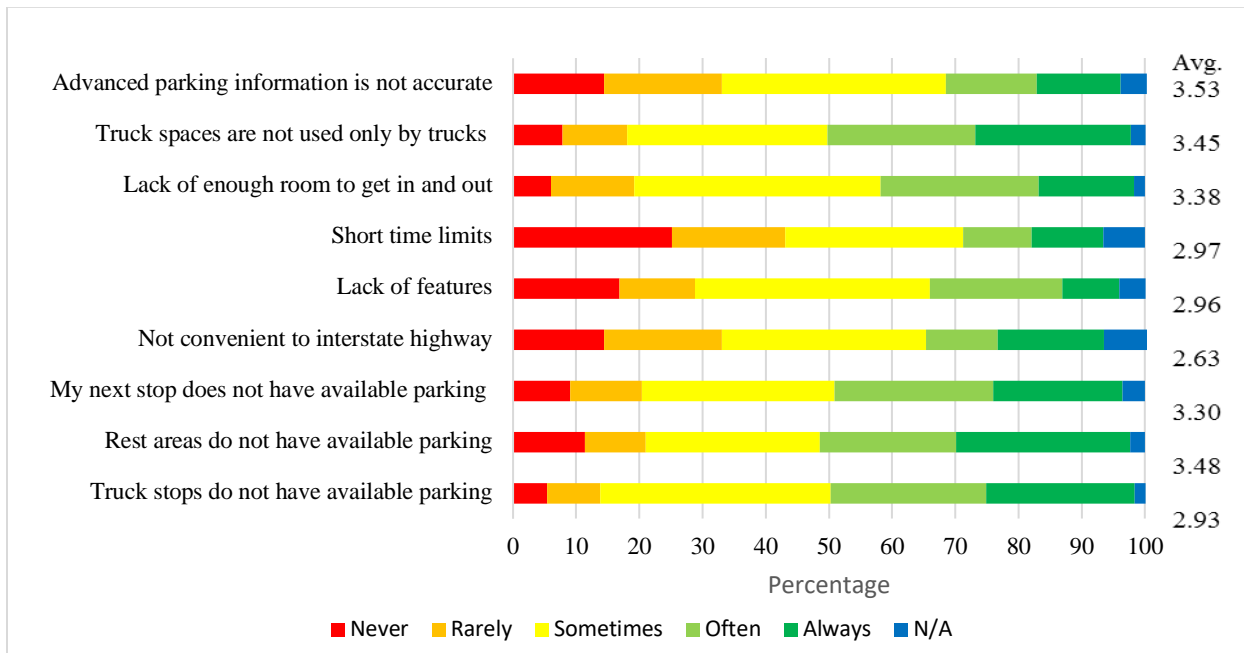


FIGURE 6 Responses to observed CMV parking problems (N=167)

The vast majority of the respondents agreed with most of the statements. Drivers did not agree on the shortage of time limits as a hindrance to park, with one-quarter of respondents rating that the worst strategy to alleviating the truck parking problems. Drivers were neutral on the inconvenience of CMV parking facility to an interstate highway, lack of features at a parking facility, and inaccuracy of advanced parking. The most important issue to CMV drivers is the lack of available parking at parking facilities. For instance, 86% of drivers agree that there is a shortage of parking at privately-owned rest facilities, which is consistent with Chen et al. (9). In that study, 90% of CMV drivers had difficulty in finding available parking spaces. The lack of available CMV parking spots at privately-owned rest facilities and more publicly-owned rest facilities were the most important parking problems encountered by CMV drivers while the issue of shorter time limits was of least importance to CMV drivers.

A similar follow-up question asked drivers to rate reasons why interstate off- and on-ramps are often used for CMV parking on a Likert scale from 1 to 5, 1 being “least likely” and 5 being “most likely”. This question allowed the possibility for a further investigation on whether there are other reasons why drivers park illegally along interstate ramps shoulders (FIGURE 7). Drivers agreed that the reason for parking along ramps is due to a lack of available parking at nearby facilities and unavailability of a nearby parking facility along the travel corridor. Respondents were relatively neutral on time limits, ease of circulation, and security. However, the respondents disagreed that availability of better lighting on ramps than in parking facility as a reason to prompt them to park along highway entrance and exit ramp shoulders.

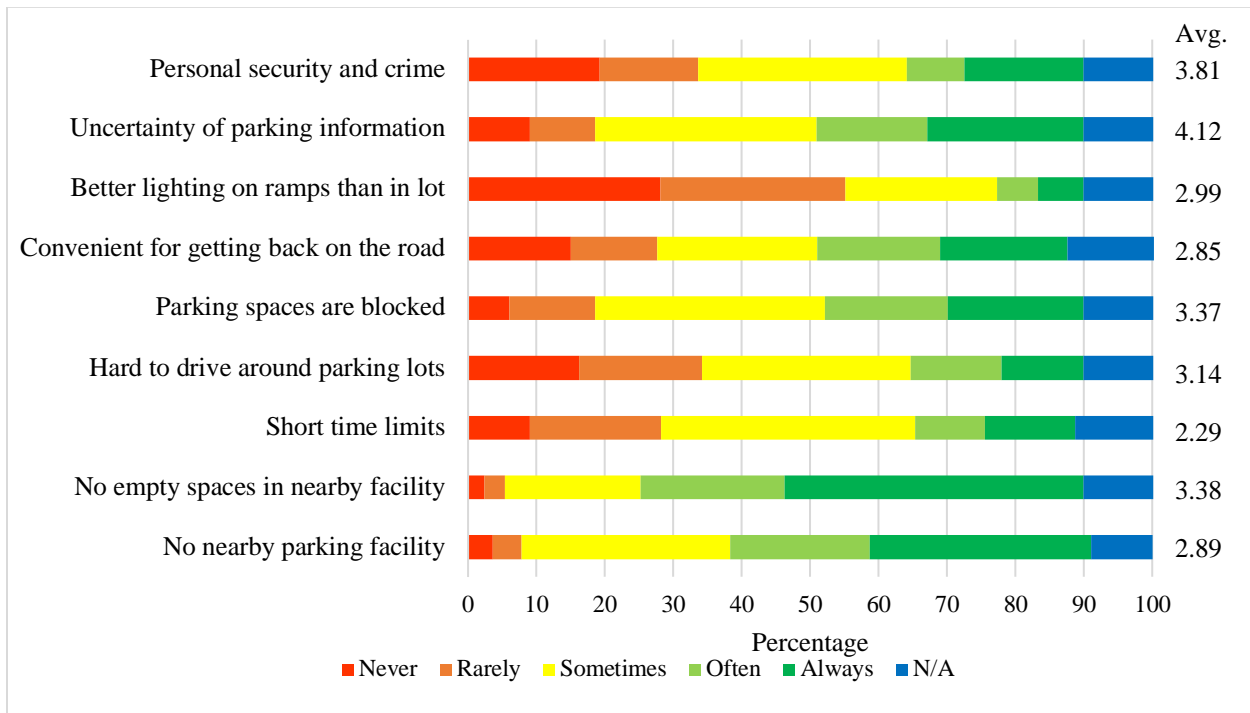


FIGURE 7 Distribution of responses in percentage to reasons why drivers park along interstate entrance and exit ramp shoulders (N=167)

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Recommendations for Policy

This study examined Tennessee’s truck parking in facilities in addition to inventorying the usage of ramp shoulders for overnight parking. Of the 94 truck facilities, 73 of them had a utilization rate of 75% or larger with an average usage of 90%. There is an apparent shortage of parking along Interstates 24, 65, and 75, with Interstate 24 having only four available parking spaces over a 185-mile corridor. Significant correlations were developed between the number of CMV along ramps and various ramp attributes. Through the responses of a survey on parking issues, the consensus was drivers perceive there is a shortage of parking and they do not prefer to park on ramps. While other aspects of parking are correlated with behavior, simple lack of available parking overwhelmingly dominates the results. Parking on ramps is the most obvious response. The most popular (among CMV drivers), and likely effective, solution to reduce ramp parking is to build more public and private rest facilities. CMV drivers specifically mention that it is nearly impossible to find available parking spots between 7 pm and 4 am with a majority of drivers stating they keep driving if they cannot find a parking space. To the extent that private parking providers do not have a market motivation to build more parking, the public sector is tasked with balancing competing budget needs for more parking facilities with general complacency and potential liability associated with allowing underregulated and informal ramp parking.

Private and public-sector technologies on smartphone applications can provide better information to drivers, such as TA TruckSmart™ and Waze™, as well as crowdsourced technologies like Truckers Path™. In addition to ITS technologies can positively influence

parking supply management and planning by allowing better preparation of overnight parking and allow CMV drivers to get up-to-the-minute information of parking availability. However, the usage of smartphones in acquiring parking information could exacerbate distracted driving challenges, but there is an observed necessity for CMV drivers in finding available parking until there is more capacity. Moreover, even smartphone apps with perfect information only begin to solve challenges with mismatched supply and demand, and do not begin to solve fundamental supply shortage problems which are encountered on many Tennessee interstates.

6.2 Deliverables and Benefits to TDOT

This work is the first major inventory of truck parking in over 15 years on TDOT's Interstate highway system. Much has changed in the transportation system in that time. As new technologies are developed to assist truck drivers in finding available parking facilities, there is a strong finding in this study that many corridors are oversaturated and only more truck parking can meet the increase in demand. This study's systematic and statewide inventory gives TDOT planners and engineers the tools to plan for more parking in areas with the most severe shortages, or in areas where informal parking creates a significant safety risk. This report, the primary deliverable of the project, provides some insight into the areas where parking volume exceeds supply. Moreover, the raw data collected is shared in both Excel database format in addition to ESRI GIS Shapefile format for mapping and other analysis. Analysts at TDOT can use the data to invest strategically or incentivize private investment to stem the safety challenges in Tennessee associated with increased CMV traffic.

7 ACKNOWLEDGMENTS

The authors thank the Tennessee Department of Transportation and the Southeast Transportation Center for their support in this project. The authors express their gratitude to the students Marquise Webb and Brandon Whetsel who gathered peak parking data and recorded the ramp parking and parking facilities, and Brad Freeze at TDOT for assistance in with data and project design. The authors also thank Zane Pannell, Kevin Robinson, and Fuad Tuhaye for assistance in the survey development and implementation.

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9 Appendix A Maps of Truck Ramp Parking



FIGURE A1 Illegal ramp parking in Tennessee

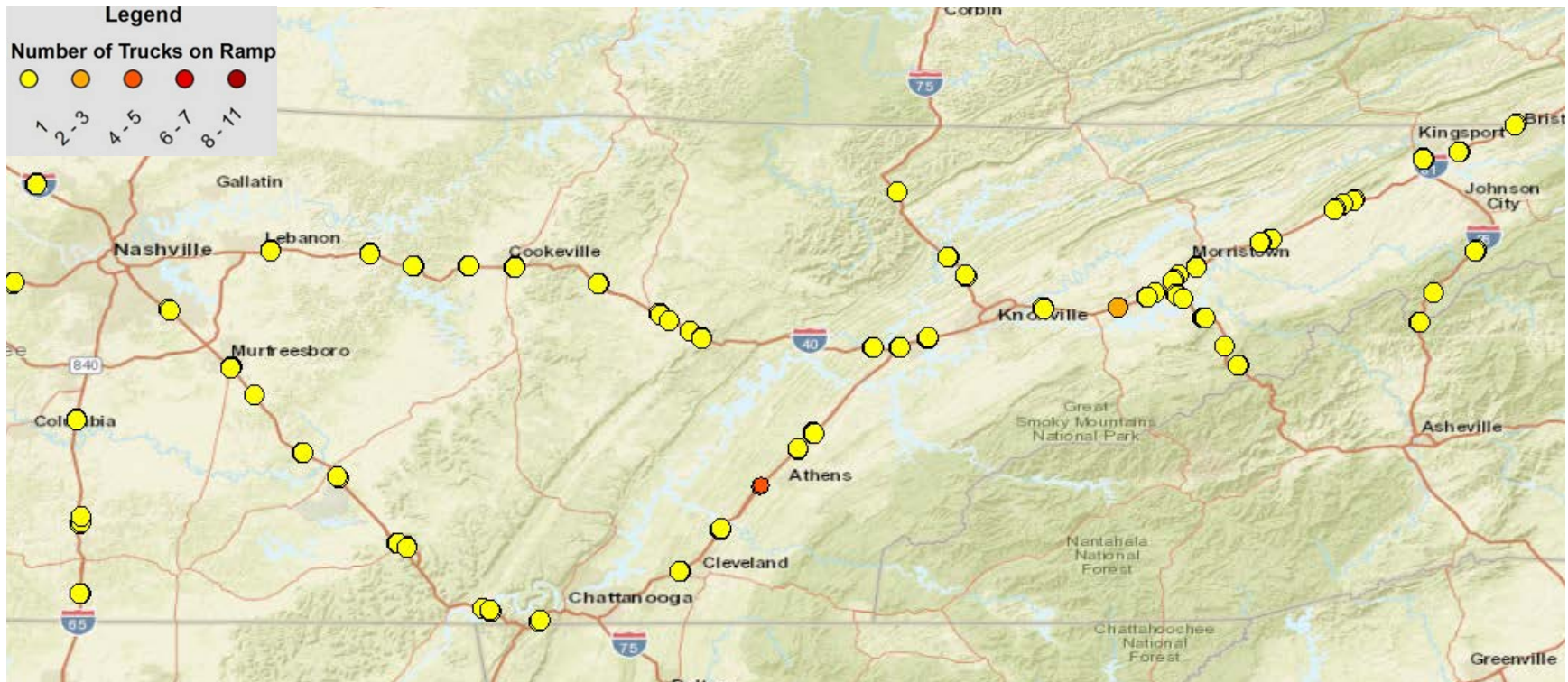


FIGURE A3 Illegal ramp parking in East Tennessee

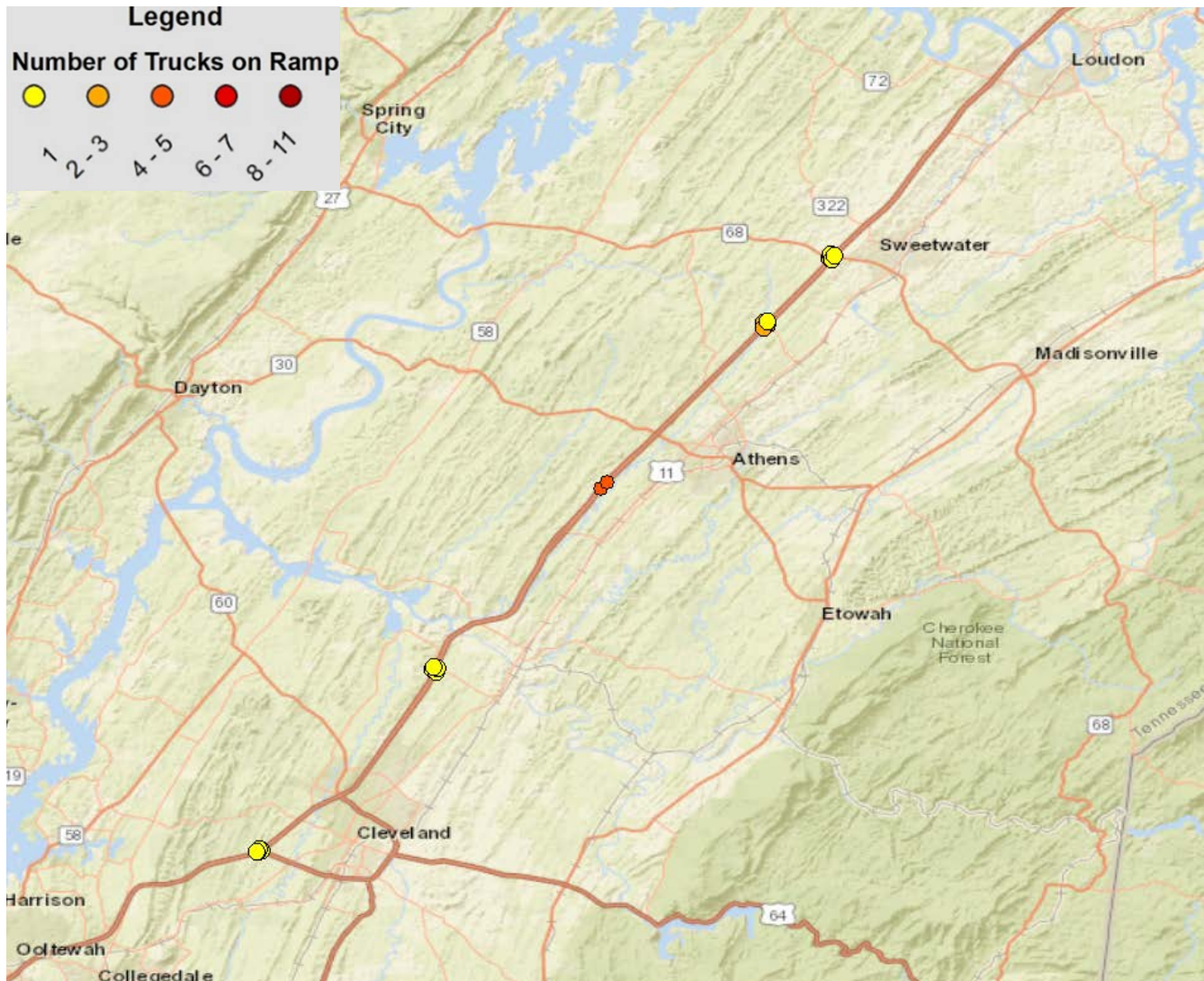


FIGURE A5 Illegal ramp parking in Athens, Tennessee



FIGURE A6 Volume to capacity of CMV facilities in West Tennessee

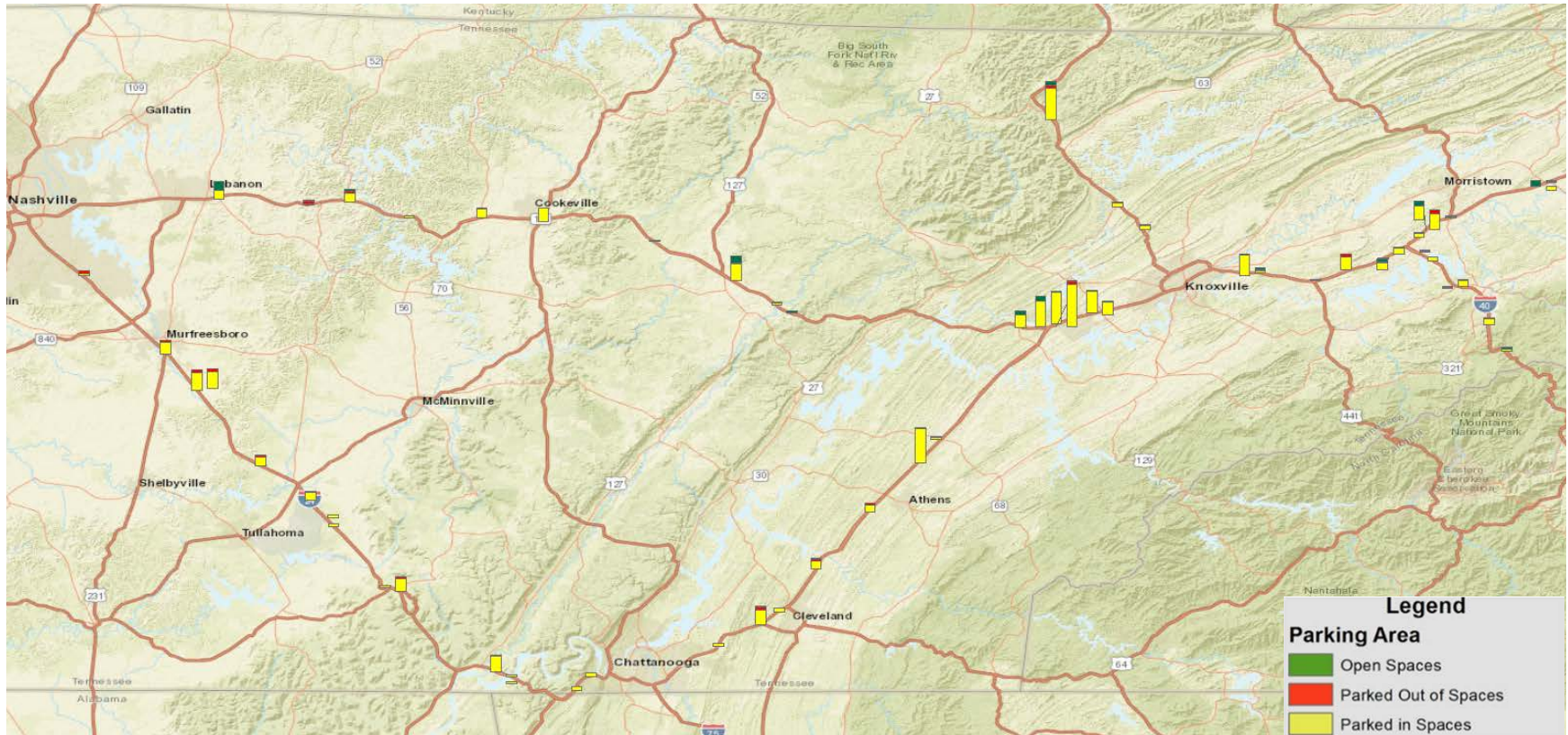


FIGURE A8 Volume to capacity of CMV facilities in East Tennessee

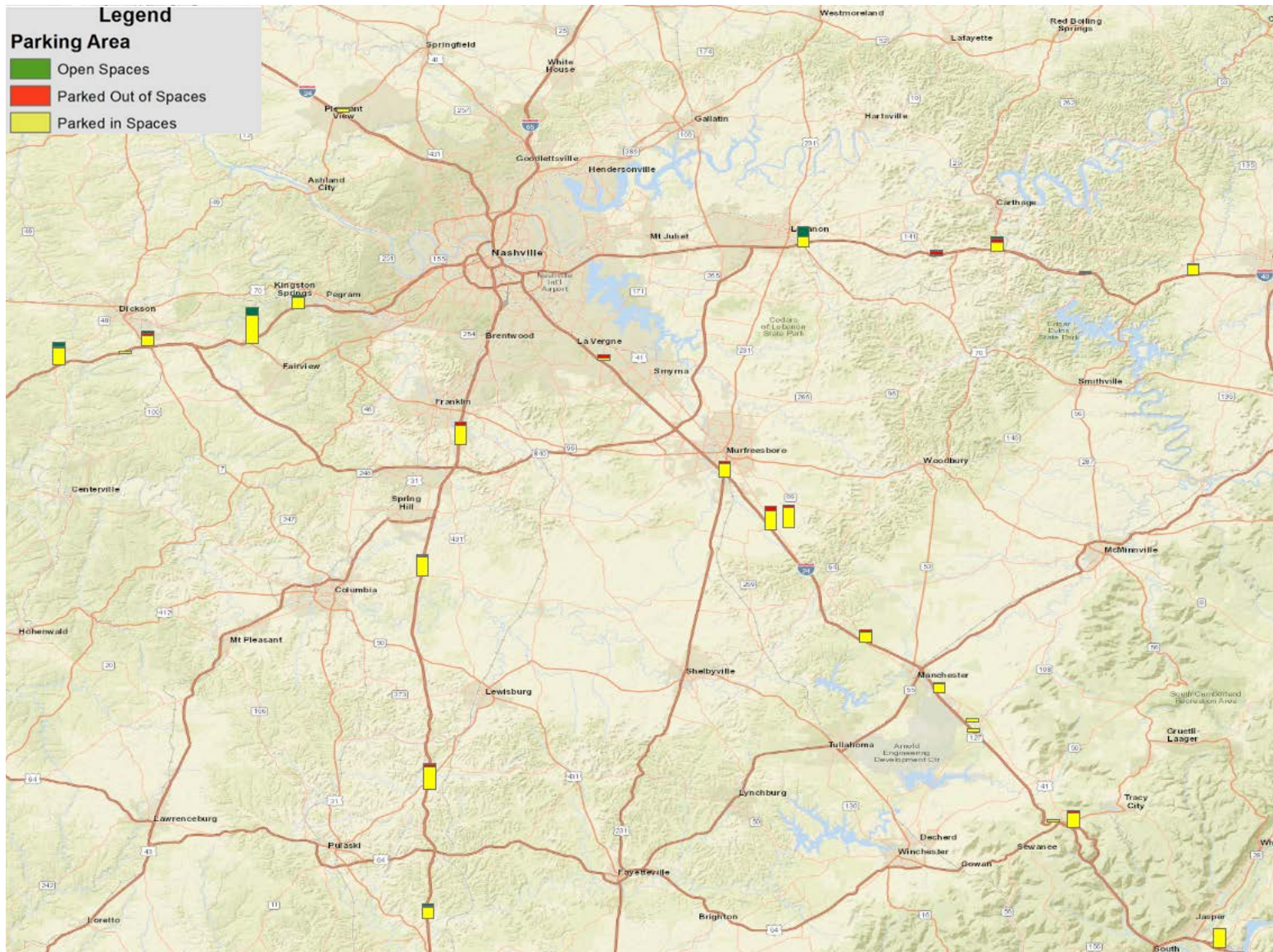


FIGURE A9 Volume to capacity of CMV facilities of Interstate 24

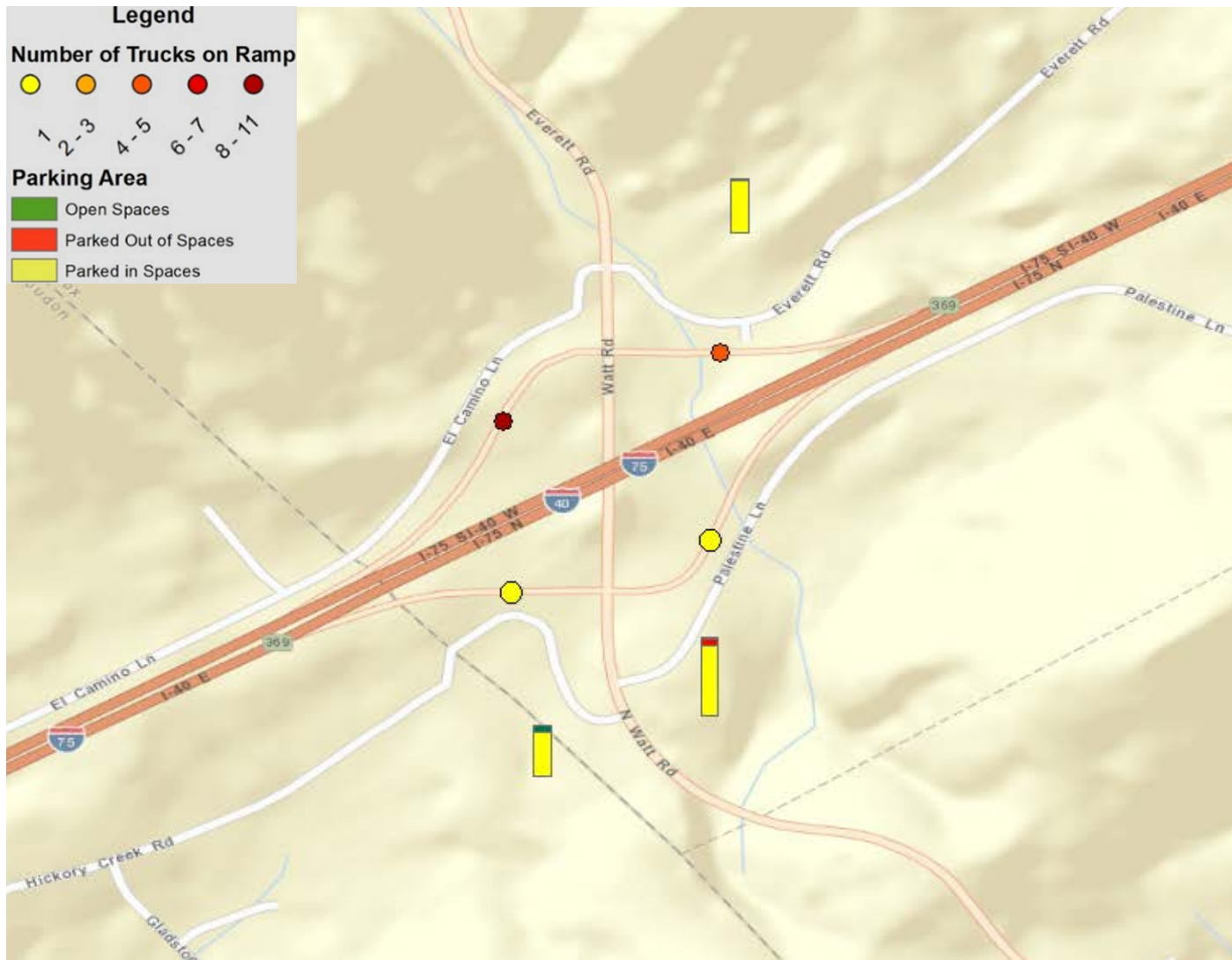


FIGURE A10 Illegal ramp parking with volume to capacity ratio of exit 369 on Interstate 40/75 in Knoxville, Tennessee



FIGURE A11 illegal ramp parking with volume to capacity ratio on Interstate 40 near Dandridge, Tennessee

10 Appendix B Survey Instrument

The University of Tennessee-Knoxville
 Department of Civil and Environmental Engineering
 223 Perkins Hall Knoxville, Tennessee 37996

Truck Driver Overnight Parking Needs and Preferences Survey (All responses are anonymous and confidential)

1. Approximately how many days do you sleep away from home while driving each month? _____ days
2. If you park to sleep, when is the decision **USUALLY** made about where you'll park?
 - Before I start driving
 - My company decides (ex. Dispatcher)
 - As I am driving
 - Other (please specify): _____
3. In a typical month, what percentage of times do you park in the following places?

I stopped to rest...	Percentage of times parked
In a rest area parking lot	
In a truck stop parking lot	
In a parking lot not designated for truck parking (e.g., park & ride)	
On an interstate entrance/exit ramp	
In a sleeper berth while team driver drives	
At a loading/unloading terminal	
Other (Please specify) _____	

4. On a scale from 1 to 5 (Almost Never to Almost Always) please indicate **HOW OFTEN** you encounter each of the following parking situations (Please Circle.)

Parking Situation	Almost Never		Sometimes		Almost Always
Truck stops do not have available parking	1	2	3	4	5
Rest areas do not have available parking	1	2	3	4	5
My next stop does not have available parking	1	2	3	4	5
Available parking is not convenient to the interstate highway	1	2	3	4	5
The parking facility does not have the features I need	1	2	3	4	5
Parking time limits do not allow enough time for me to park	1	2	3	4	5
There is not enough room to get in and out of available spaces.	1	2	3	4	5
Truck spaces are not used only by trucks	1	2	3	4	5
Advanced parking information is not accurate	1	2	3	4	5

5. What do you do if parking is full at a parking facility? (Please mark all that apply.)
 - Park on an interstate on-ramp shoulder
 - Park on an interstate off-ramp shoulder
 - Park on a loading terminal
 - Keep driving until the next available parking facility
 - Other (please specify): _____

6. On a scale from 1 to 5 (Almost Never to Almost Always) **WHAT DO YOU THINK** are the reasons that interstate on/off ramps are sometimes used for truck parking? (Please Circle.)

Reason	1	2	3	4	5
No nearby parking facility	1	2	3	4	5
No empty spaces in nearby truck stops/rest areas	1	2	3	4	5
Nearby parking spaces have time limits that are too short	1	2	3	4	5
Hard to drive around parking lots	1	2	3	4	5
Empty nearby parking spaces are blocked by other trucks, cars, or RVs	1	2	3	4	5
The on/off ramp is convenient for getting back on the road	1	2	3	4	5
Better lighting on ramps than in lot	1	2	3	4	5
Uncertainty of available rest area and truck stop parking	1	2	3	4	5
Personal security and crime	1	2	3	4	5

7. What is the major cause of uncertainty of truck parking availability? (Please mark all that apply.)

- Too little information available on truck parking Inaccurate parking information
 Other (please specify): _____

8. How do you find out about truck parking information? (Please mark all that apply.)

- Electronic visual display in vehicle Radio in vehicle (ex. CB) The Internet Travel Guide
 GPS Smart-Phone/iPhone application Interstate Signs Tablet (iPad/Android based)
 Dispatcher/carrier call ahead Show up at parking facilities without checking availability
 Other (please specify): _____

9. What type of **UP-TO-THE-MINUTE** information on truck parking availability would help you plan your stops while you drive? (Please mark all that apply.)

- Location of truck parking facilities along the road I'm traveling
 Number of truck parking spaces available at upcoming parking facilities
 Length of time limits on upcoming truck parking spaces
 Features (ex. shower) that are available at upcoming parking facilities
 Other (please specify): _____

10. How would you like to receive **UP-TO-THE-MINUTE** information on truck parking availability? (Please mark all that apply.)

- Electronic visual display in vehicle Radio in vehicle (ex. CB) The Internet
 GPS Smart-Phone/iPhone application Interstate Signs Tablet (iPad/Android based)
 Dispatcher/carrier Other (please specify): _____

11. Which of the following electronic devices do you own and travel with? (Please mark all that apply.)

- Smart Phone GPS Laptop Radio in vehicle (ex. CB)
 Tablet/iPad Cellular Phone Telematics Device

12. **HOW MUCH** would you be willing to pay as a **MONTHLY** subscription fee for Smart-Phone/iPhone application (app) showing up-to-date information on available parking spaces and amenities at major private and public rest areas? **(Please mark one.)**
- I would not use this app \$1-\$3 \$4-\$6
 \$7-\$9 More than \$10 I would use a free app that has targeted advertising
13. On this trip, where did you last park your truck to sleep? **(Please mark one.)**
- I have not slept yet Truck stop Rest area Interstate on-ramp shoulder
 Interstate off-ramp shoulder Loading terminal A nearby non-interstate roadway
 Other (please specify): _____
14. Where is the next place that you plan to park your truck to sleep? **(Please mark one.)**
- Truck stop Rest area Interstate on-ramp shoulder
 Interstate off-ramp shoulder Loading terminal A nearby non-interstate roadway
 Unknown Other (please specify): _____
15. Have you seen shortages of parking spaces... **(Please mark one.)**
- Increase over the last 5 years? Decrease over the last 5 years?
 Remain the same over the last 5 years? Don't know
16. In which state is your CDL based? _____
17. What is your age? _____ years
18. What is your gender?
- Male Female
19. What is your race/ethnicity?
- American Indian/ Native American White/ Caucasian
 Asian Pacific Islander
 Black/ African American Other (please specify): _____
 Hispanic/ Latino
20. What is your current marital status?
- Single Married Divorced Separated Widowed
21. Which of the following categories best describes you? **(Please mark one.)**
- Independent owner/operator (1 power unit) Driver for a *mid-sized* carrier (11-100 power units)
 Independent owner/operator (multiple units) Driver for a *large-sized* carrier (over 100 power units)
 Driver for an owner/operator Other (please specify): _____

Driver for a *small-sized* carrier (2-10 power units)

22. How often do you participate in TEAM driving?

Almost Never Rarely Sometimes Frequently Almost Always

23. On a scale from 1 to 5 ("Almost Never Important" to "Almost Always Important"), please rate **HOW OFTEN** the following features are important to you when you park at a truck stop or rest area after you have reached your daily hours of service. (Please circle.)

Feature	Almost Important	Never Important	sometimes	Almost Important	Always Important
Convenience to interstate highway	1	2	3	4	5
Well-lighted parking lot	1	2	3	4	5
Prepaid fuel cards accepted	1	2	3	4	5
Internet connections (Wi-Fi)	1	2	3	4	5
Security presence	1	2	3	4	5
Showers	1	2	3	4	5
Repair facilities	1	2	3	4	5
Restaurant	1	2	3	4	5
Fuel price	1	2	3	4	5

24. List the states where you were scheduled to pick up or drop off loads on this trip (from your origin to final destination).

1. (Origin) _____
2. _____
3. _____
4. (Destination) _____

25. What are the concerns on parking at rest areas/truck stops?

26. What encourages you to not park on on/off ramps?

FIGURE B11 Comprehensive survey

The University of Tennessee-Knoxville
Department of Civil and Environmental Engineering
223 Perkins Hall Knoxville, Tennessee 37996

Truck Driver Overnight Parking Needs and Preferences Survey
(All responses are anonymous and confidential)

1. Each month, approximately how many days do you sleep away from home while driving? _____ days
(1-31 days)
2. If you park to sleep, when is the decision **USUALLY** made about where you'll park?
 Before I start driving My company decides (ex. Dispatcher)
 As I am driving Other (please specify): _____
3. What do you do if parking is full at a parking facility? **(Please mark all that apply.)**
 Park on an interstate on-ramp shoulder Park on an interstate off-ramp shoulder
 Park on a loading terminal Keep driving until the next available parking facility
 Other (please specify): _____
4. How do you find out about truck parking information? **(Please mark all that apply.)**
 Electronic visual display in vehicle Radio in vehicle (ex. CB) The Internet Travel Guide
 GPS Smart-Phone/iPhone application Interstate Signs Tablet (iPad/Android based)
 Dispatcher/carrier call ahead Show up at parking facilities without checking availability
 Other (please specify): _____
5. What type of **UP-TO-THE-MINUTE** information on truck parking availability would help you plan your stops while you drive? **(Please mark all that apply.)**
 Location of truck parking facilities along the road I'm traveling
 Number of truck parking spaces available at upcoming parking facilities
 Length of time limits on upcoming truck parking spaces
 Features (ex. shower) that are available at upcoming parking facilities
 Other (please specify): _____
6. How would you like to receive **UP-TO-THE-MINUTE** information on truck parking availability? **(Please mark all that apply.)**
 Electronic visual display in vehicle Radio in vehicle (ex. CB) The Internet
 GPS Smart-Phone/iPhone application Interstate Signs Tablet (iPad/Android based)
 Dispatcher/carrier Other (please specify): _____
7. Which of the following electronic devices do you own and travel with? **(Please mark all that apply.)**
 Smart Phone GPS Laptop Radio in vehicle (ex. CB)
 Tablet/iPad Cellular Phone Telematics Device
8. In which state is your **CDL** based? _____

9. List the states where you were scheduled to pick up or drop off loads on this trip (from your origin to final destination).

- 1. (Origin) _____
- 2. _____
- 3. _____
- 4. (Destination) _____

10. Which of the following categories best describes you? (Please mark one.)

- Independent owner/operator (1 power unit)
- Independent owner/operator (multiple units)
- Driver for an owner/operator
- Driver for a *small-sized* carrier (2-10 power units)
- Driver for a *mid-sized* carrier (11-100 power units)
- Driver for a *large-sized* carrier (over 100 power units)
- Other (please specify): _____

11. What is your age? _____ years

12. What is your gender?

- Male
- Female

13. What is your race/ethnicity?

- American Indian/ Native American
- Asian
- Black/ African American
- Hispanic/ Latino
- White/ Caucasian
- Pacific Islander
- Other (please specify): _____

14. What is your current marital status?

- Single
- Married
- Divorced
- Separated
- Widowed

15. What is the most important parking issue for you?

FIGURE B2 Short form survey