TENNESSEE SMARTPARK PILOT

Final Report

Submitted to
Tennessee Department of Transportation

Principal Investigators
Mihalis M. Golias and Sabyasachee Mishra

Research Assistants
Mania Flaskou, and Samuel Jordan

University of Memphis

3/3/2021

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-CFL/TD-0x-00x		

4. Title and Subtitle	5. Report Date
Tennessee SmartPark Pilot	April 2018
	6. Performing Organization Code
7. Author(s) Golias M., Misha S., Flaskou M., Jordan S.	8. Performing Organization Report No.
9. Performing Organization Name and Address University of Memphis 3815 Central Avenue Memphis, TN, 38152	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Tennessee Department of Transportation James K. Polk Building, Suite 900 505 Deaderick St., Nashville, TN 37243-0344 Central Federal Lands Highway Division	13. Type of Report and Period Covered 14. Sponsoring Agency Code HFTS-16.4

15. Supplementary Notes

COTR: First & Last name, FHWA CFLHD; Advisory Panel Members: List First & last names. This project was funded under the FHWA Federal Lands Highway Technology Deployment Initiatives and Partnership Program (TDIPP). Or the Coordinated Technology Implementation Program (CTIP).

16. Abstract

The technology that SmartPark project uses includes overhead laser scanners, side-mounted laser scanners, and light curtains (CURs). The laser scanners and CURs are able to produce two-dimensional vehicle profiles, showing height (or width) and length. The detectors use laser beams to detect the presence of a vehicle. When a vehicle passes beneath the scanner's beams, the beams are either reflected (in the case of the laser scanners), or obstructed (in the case of the CURs). These detection technologies are implemented at the ingress and egress points of the truck parking area at the Northbound Rest area at Mile Marker 45 in Athens, TN to monitor vehicles entering and exiting the site. The data collected at these sites will be used in this project for measuring and evaluating the performance of the system operations and feasibility of continuing and expanding the program to multiple truck parking areas. This report summarizes the research activities and results of an operational analysis including system performance measures using data collected from existing installations at two SmartPark locations in TN, and a survey of SmartPark users. The report also presents a business plan for a Tennessee SmartPark Program that includes a review of potential future SmartPark installation sites or list of rest areas where this technology could be deployed.

17. Key Words	18. Distribution Statement
SMARTPARK, TRUCK PARKING, REST AREAS	No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	66	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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This research was funded through the State Research and Planning (SPR) Program by the Tennessee Department of Transportation and the Federal Highway Administration under RES #:2016-08, Research Project Title: Tennessee SmartPark Pilot .

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INTRODUCTION

Fatigue is one of the major causes of truck accidents on the roadway. Truck drivers become tired and are not able to drive especially when they do not comply with hours-of-service (HOS) regulations and drive for long periods of time without resting. According to the Federal Motor Carrier Safety Administration (FMCSA), more than 750 people die and 20,000 more are injured each year from accidents attributed directly to fatigued truck drivers. One of the most substantial causes of noncompliance with driving regulations is the lack of awareness (or simply lack) of available truck parking. FMCSA created the SmartPark initiative which is designed to match demand for truck parking with availability. This initiative includes truck parking detector technologies integrated into a real-time truck parking information system for use by truck drivers.

The SmartPark project is intended to improve supply and demand for truck parking by using Intelligent Transportation System (ITS) technology. Such technology could be operational on a broad scale and could be used to accommodate part of the high demand for truck parking with existing resources. This type of technology will support the efficient, economic and effective utilization of current existing facilities. Note though that it has been evident from a number of studies that the current number of public and privately owned truck rest areas in the US are insufficient to accommodate the ever increasing number of trucks; nearly 40% of trucks parked overnight in Tennessee park along shoulders of ramps and throughways, or in undesignated locations inside rest areas and pull-out areas *(1)*. Improving truck driver's ability to find and locate long-term parking spaces will enhance the safety of commercial vehicle operations by enabling drivers to meet the Hours of Service regulations.

The technology that SmartPark project uses includes overhead laser scanners, side-mounted laser scanners, and light curtains (CURs). The laser scanners and CURs are able to produce two-dimensional vehicle profiles, showing height (or width) and length. The detectors use laser beams to detect the presence of a vehicle. When a vehicle passes beneath the scanner's beams, the beams are either reflected (in the case of the laser scanners), or obstructed (in the case of the CURs). These detection technologies are implemented at the ingress and egress points of the truck parking area at the Northbound Rest area at Mile Marker 45 in Athens, TN to monitor vehicles entering and exiting the site. The data collected at these sites will be used in this project for measuring and evaluating the performance of the system operations and feasibility of continuing and expanding the program to multiple truck parking areas.

TDOT has been a partner in a Federal Motor Carrier Safety Administration's (FMCSA) SmartPark Pilot Project on the I-75 Corridor between Chattanooga & Knoxville. ITS technologies have been deployed at the Northbound Rest area at Mile Marker 45, and at an upgraded truck inspection station Northbound Mile Marker 23 to create a SmartPark Corridor. Truck parking availability is monitored by cameras, ingress and egress laser sensors, and radar. Intelligent Transportation Systems (ITS) technologies improve transportation safety, accessibility and mobility and develop productivity by incorporating advanced technologies into transportation infrastructure. ITS comprises of a wide range of wireless and conventional communications-based information and electronic technologies. TDOT supports the advancement of ITS through investments in major research initiatives and comprehensive studies. One of the most prominent ITS technologies have been deployed at a rest area in Tennessee to improve supply and demand for truck parking. With this program, TDOT will be able to decrease the need for expanding existing truck parking facilities or rest areas more efficiently, economically, and effectively utilizing current existing facilities. The ultimate benefits are wide-ranging and powerful and they will be felt by all the truck drivers delivering good comfortably and safely.

This report summarizes the research activities and results of an operational analysis including system performance measures using data collected from existing installations at two SmartPark locations in TN, and a survey of SmartPark users. The report also presents a business plan for a Tennessee SmartPark Program that includes a review of potential future SmartPark installation sites or list of rest areas where this technology could be deployed.

The rest of the report is structured as follows. The next section provides a review of the relevant literature followed by a description of the SmartPark project in TN. The fourth section presents the operational analysis results of both sites in TN. The fifth section provides a discussion on the survey results. The last section provides guidelines for a business plan, candidate locations for additional implementation of the SmartPark technology and concludes the report.

LITERATURE REVIEW

This section provides a review of the relevant literature and is divided into two parts; each focusing on a region where intelligent truck parking has been implemented. First, a review of intelligent truck parking in the US is presented in order to show the current state of intelligent truck parking in the US, and to show current technology in use. In the second part of this literature review, intelligent truck parking is presented as it has been implemented in the European Union.

Intelligent Truck Parking in the US

In 2002 *(2)* a study by the Federal Highway Administration (FHWA) on the truck parking sufficiency suggested the use of ITS to provide commercial vehicle (CMV) drivers with real-time information on the location and availability of truck parking. The University of Virginia *(3)* proposed a methodology for implementing and evaluating a truck parking information system in 2004 to help transportation agencies and engineers clarify the concepts and frameworks of such a system. In their proposal, in-pavement inductive loop detectors and video image processors were recommended for parking data collection units while variable message signs (VMS) and an internet website for information display.

In 2005, the John A. Volpe National Transportation Systems Center completed a study entitled "ITS and Truck Parking" for the FMCSA *(4)* The same year the Federal Motor Carrier Safety Administration (FMCSA) introduced its truck parking program, entitled SmartPark, which assessed the utilization of different ITS technologies in truck parking in order to better match supply and demand. According to FMSCA, such a system should monitor occupancy and availability at public and private truck parking sites, distribute parking availability information to interested parties by various means, (i.e. variable message signs, highway advisory radio, and Web sites), provide the opportunity to drivers to reserve a parking spot, operate unattended 24/7, be inexpensive to install and operate, and be economically self-sustaining *(5)*.

From 2007 to 2009, the SmartPark project (funded by FMCSA) tested two separate technologies: video imaging and magnetometry *(5, 6)*. The test site for the video technology was the Charlton Westbound Service Center, a public truck parking area on the Massachusetts Turnpike (Interstate 90). The two test sites for the magnetometer were a public rest area located at mile marker nine (MM9) on Interstate 95 in Mansfield, MA and a private truck stop, Interstate Travel Plaza (ITP), located on U.S. Route 1 in Wrentham, MA. Test results showed that video imaging did not meet the performance requirements at nighttime and magnetometry did not meet the performance requirement for vehicle classification.

The Michigan Department of Transportation (MDOT) and FHWA developed the Truck Parking Information and Management System (TPIMS) on I-94. The system that consists of 15 public and private parking areas *(7)* detects available and filled parking spots using video detection. Magnetic, induction, thermal, and on-site observation is also used *(8)*. This system is the first to provide real-time information about available parking spots through dynamic roadside truck parking signs, MDOT's Mi Drive traffic information website (www.michigan.gov/drive), Truck Smart Parking Services website and smartphone applications (www.trucksmartparkingservices.com), and a fleet of pilot trucks equipped with on-board connected vehicle equipment *(9)*.

The Minnesota DOT in collaboration with FHWA started the implementation of an intelligent truck parking system in 3 rest areas on I-94 in 2012 using a network of cameras to monitor parking availability at truck stops to automatically identify available spaces in real time. By the end of the testing period in 2014 it was found that the system was performing with 95% accuracy at any weather conditions. Today, there are a total of five locations (four public and one private) in the Minnesota system that informs drivers about parking availability via a website, in-cab messaging, and variable message signs *(10)*.

(11) published a research paper on deploying a wireless vehicle detection system with ground sensors in a rest area 2 mi west of Tallahassee, FL. Scope of the research was first, to determine trends for truck parking at Florida's rest areas and second, to develop a suitable smart parking management system. The output of the data collection (total parking utilization in all rest areas in the state) was used to select the most suitable site for the system implementation as the two criteria were the level of truck parking capacity problem and the location. The system uses historic data to predict rest area occupancy. In the study two prediction models were tested but both of them had low accuracy rates by the time the paper was published mainly due to low historic data.

The National Association of Truck Stop Operators (NATSO) foundation in collaboration with the American Trucking Association and the American Transportation Research Institute (ATRI) announced the Truck Parking Leadership Initiative in 2016 to help truck drivers find available truck parking *(12)*. Since a nationwide electronic truck parking system is not available yet this initiative relies on public and private truck parking providers to report the number of available spaces in the lot through an app called Park My Truck without further equipment installation. Park My Truck became available to truck drivers and trucking companies via internet or smartphone apps at the end of summer 2016.

Intelligent Truck Parking in Europe

Since 2007 the European Union with the EasyWay project acknowledges the importance of ITS deployment in truck rest areas to optimize their use due to limited availability, and for safety and environmental reasons *(13)*. The level of information and the technology used can differ in each location as shown in Table 1.

Table 1: Level of service criteria: intelligent and secure truck parking *(13)*

Core Criteria	Level 0 (no service)	Level A	Level B	Level C	Level D	Level E
Information on truck parking areas	None	Basic Static	Advanced Static	Real-time (dynamic)	Real-time and forecast for one point	Real-time and forecast for a section/for a trip
Transmission of information	None	Static Sign, maps	VMS for single site	VMS covering several sites, Internet broadcast	ON-Board technologies (App, telematics services)	
Reservation	None	Telephone	Web-based service via internet browser	ON-Board technologies (App, telematics services)		

The pilot project around Vienna, Austria for instance consists of 10 locations *(14)* equipped with CCTVs and the information (FREE / FULL) is provided via VMS and on their website. In France individual sensors installed in the floor under each parking spot are used to identify the FREE / FULL parking lots for the 61 largest VINCI group's private truck stops. The information is provided via VMS, 3 to 5 km before each parking area. In 2008 the Société des Autoroutes Paris-Normandie (SAPN) started a truck parking program on motorway A13 that provides real-time occupancy information for 12 truck parking areas in France. The signs indicate the number of available parking spaces for the next three following areas *(13)*.

In Germany, there are few examples of intelligent truck parking in use. In Aichen, the number of free parking spaces is displayed on VMS and the occupancy is calculated with magnetic sensors at the entrance and at the exit. At the Telematic Controlled Parking (TCP) at the Montabaur Pilot by the A3 motorway in Rheinland-Pfalz, the drivers use a terminal in the facility to enter both the desired departure time and vehicle type and a parking space is then allocated either behind a vehicle with an earlier departure time or at the front of a new lane. In "Bundesanstalt für Straßenwesen" the expected latest departure is displayed on dynamic signs at the beginning of parking line and truck drivers choose themselves which parking place is best for them. In south-west Germany 20 "Autohöfe" (private truck stops) are connected to a reservation system that allows booking of free or not free of charge truck parking places via Internet or by telephone. The parking areas are not always equipped with special technical devices since the system works with a parking attendant already working for the truck stop, or with technical infrastructure at the parking gate *(13)*.

In Denmark, the Ustrup East parking location is a fully automated truck parking location. The system directs and allocates vehicles to columns (lanes), depending on their departure times (i.e. vehicles that are going to leave the rest area immediately after one another are also placed after one another in the same column). Drivers enter to the system how long they are going to stay in the parking when they enter the facility, and lane lights in the pavement show them the way to their designated lane. If a driver parks in a wrong lane the system automatically closes the given lane until the vehicle has left the area. Industrial lasers are used to measure the remaining capacity of the lanes with accuracy of 1 cm (0.40 in) and VMS are used on the highway to show the number of available parking spaces *(13)*. At the Danish E20 highway (part of the Scandria corridor, which connects capitals and metropolitan regions along the shortest way from Scandinavia) real-time information about the number of available truck parking spots is displayed via VMS. Wireless floor mounted sensors are used to detect if a truck parking space is occupied and for how long *(15)*.

In 2010 the Hungarian motorway operator State Motorway Management Company started a pilot project to provide dynamic information for the busiest rest area on the M1 corridor *(16)*. The number of available parking spaces is based on a 3D video analysis system that was found to be the most suitable equipment for special weather conditions during winter time. The truck parking area is covered by 3 double surveillance cameras. The number of free places is shown on a VMS 15 km far from the pilot site as real-time information.

THE SMARTPARK PROJECT IN TENNESSEE

After the SmartPark project failed to achieve the required accuracy for the set performance requirements, FMCSA tested a different technology in rest areas in Tennessee in 2011. The project was split in two phases lasting 24 and 17 months respectively. For Phase I (August 2011-July 2013) a rest area on I-75 northbound (NB) at mile marker 45 (Rest Area 45) in Athens, TN was selected to test the feasibility of the used technology to collect real time parking utilization information. In Phase II (June 2013-November 2014) a second location southwest of the original location (Rest Area 23) was selected to demonstrate how two adjacent truck parking areas can be linked to divert trucks from a filled parking area to an area with available spaces by providing dynamic real time information. The locations of the selected rest areas is shown in Figure 1**.**

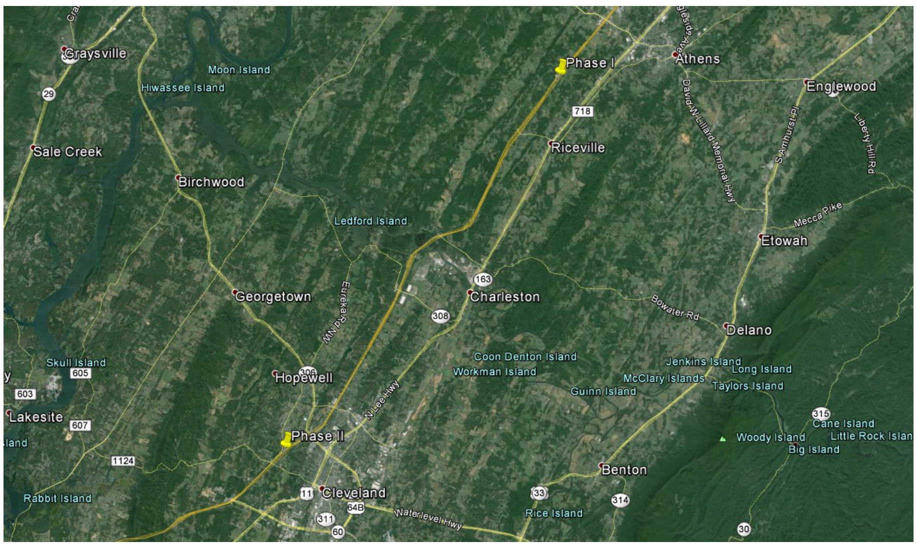

Figure 1: TN SmartPark locations
*(**Figure Source**: Google Earth)*

Phase I (August 2011-July 2013)

The selection of the primary area (Phase I) was based on requirements set by the Request for Proposal (RFP). More specifically the rest area was selected to meet the following characteristics:

1. Recently reconstructed with easily accessible truck parking spaces,
2. Single points of ingress and egress,
3. Separated truck and car parking areas,
4. Ample lighting for nighttime operations,
5. Existence of several sites upstream meeting criteria 1 through 4 for a Phase II expansion.

The detection technology used in Phase I includes a Doppler radar and laser scanners (in overhead [OH] and side [SID] configurations) and light curtains (CUR) mounted on gantry structures (Figure 2). Part of the system is also an onsite processor (to process scanner, CUR and Doppler radar signals) and an offsite server (to download and store the data in a database). Besides the detector equipment mentioned above verification tools (i.e. closed circuit television (CCTV) cameras, a network video recorder (NVR), and the project Website) are used to inspect, verify, and evaluate the system performance, and to communicate with the parking location. CCTVs are used for site monitoring and space availability validation and through the Web site the CCTV cameras are monitored and necessary corrections (discussed later in this report) are made to the system.

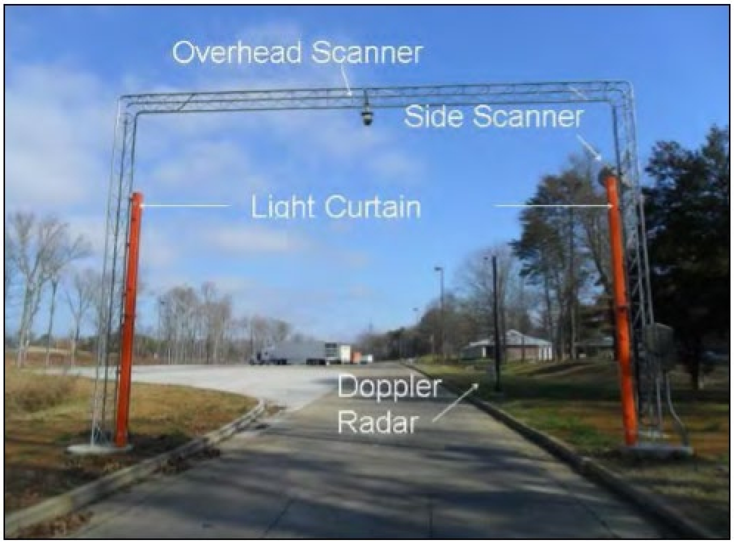

Figure 2: SmartPark detector configuration
Figure Source: **(Gannett Fleming, Inc 2013)**

The detection equipment was installed at the rest areas' ingress and egress points. The laser scanners were mounted overhead and on each side with only one laser scanner been utilized at a time. The two 10-foot CURs (two 5-foot CUR units stacked on top of each other) were mounted on each side as seen in Figure 2. CURs were only used at the ingress point due to limited funds. Laser scanner and CUR use laser beams to detect a vehicle. When a vehicle passes beneath the scanner's beams, the beams are either reflected (laser scanner), or obstructed (CURs). The Doppler radar was installed downstream of the gantry for the ingress point (and upstream for the egress) pointed back at the oncoming vehicle to detect the position and velocity of the vehicle relative to the scanned line. The detection equipment used was tested in three different detector combinations (SID-SID, OH-OH, and CUR-OH) to see which one performs best so it is used in future projects.

Laser or CUR scan data and distance and speed data provided by the Doppler radar are processed and combined by the onsite processor to determine the length and shape of the vehicle to create a two-dimensional profile of the vehicle. A vehicle class is then assigned to the observation based on this information. For this project six vehicle classes were initially defined (see

Table 2) and then replaced with four (as discussed later in this report).

Table 2: Vehicle classification *(17)*

Vehicle Class	Description
1	Vehicles with length less than or equal to 18 feet and no trailer. For example, cars and motorcycles (this class was not typical to the site, as small vehicles are directed to an adjacent lot; however, it was adopted in case such vehicles entered into the truck parking area).
2	Vehicles with length between 18 feet and 30 feet and no trailer. For example, pickup trucks or large sport utility vehicles (SUVs).
3	Vehicles with a trailer, where the combined total length was between 5 feet and 30 feet. For example, a Class 1 vehicle towing a trailer.
4	Vehicles with length between 30 feet and 50 feet and no trailer. For example, a recreational vehicle (RV) or bus.
5	Vehicles with a trailer, where the combined total length was between 30 feet and 50 feet. For example, a Class 2 vehicle towing a trailer or truck with a short trailer, such as a pickup truck towing a horse trailer.
6	Vehicles with a trailer, where the combined total length was equal to or greater than 50 feet (truck with double trailer or long single trailer).

Data collected by the detection equipment are processed by the on-site processor. The processed data provide information for the presence of a vehicle (at ingress or egress), the length of the vehicle, the vehicle class, and the vehicle shape. Apart from identifying vehicle characteristics, the processor determines the lot occupancy and the number of spaces available.

In addition to the detection equipment, verification tools were installed and incorporated into the system. The verification tools include seven CCTV cameras, a NVR and a project Website. The CCTV cameras were mounted on existing light poles and placed in the rest area in a way that all spaces in the lot and the ingress and egress gantries can be visible from a remote location. Each of the CCTV cameras is linked to the central server located onsite in the rest area equipment room.

The NVR is connected to the site CCTV cameras for video recording purposes, it can be activated or deactivated remotely, and can only keep a limited amount of video. The purpose of the NVR is to provide video for vehicle detection validation. The NVR is supplemented with a proprietary viewer that can read the NVR's proprietary video compression algorithm and files. The video can also be converted to standardized video formats using a converter.

The project Website was created to monitor the site in real time and is only accessible to authorized users. The information shared on the website is on the current occupancy of the parking lot, including available spaces, vehicle classifications, live video from the CCTVs, and historical data from any period that the system was in operation. Also, manual adjustment of the vehicle count is possible through the website. Any time the ingress or egress detector detected a vehicle a unique event is created that includes a time stamp, an event type (ingress or egress), a unique vehicle ID, the sensor type (scanner or CUR), the mounting configuration of the detector (overhead or side), the vehicle class, the number of spaces in use, the vehicle count in the lot by class, and images of the entering or exiting vehicle.

All equipment at the site is connected using a series of fiber optics and Ethernet, and communicates via a local area network (LAN) established for the project.

Phase II (June 2013- November 2014)

Phase II of the SmartPark project started in June 2013. Phase I results showed that side scanners (SID-SID) with a Doppler radar installed downstream of the gantry is the detection technology that performed best, so it was selected for use in the Phase II location. Part of the scope of Phase II was to add new components (in addition to the existing ones from Phase I) that will distribute parking availability information to truckers and allow them to use a parking reservation system. An on-site server combines signal information from the side scanner and speed information from the Doppler radar to create a profile of the vehicle that includes its length. Additional data collected and stored in the on-site server is the detector ID, date, time, length, profile and class of entering vehicle, number of vehicles in the lot, and a still-image of the detection area. Off-site servers are connected to the on-site server to collect and store data that can be used to estimate future parking availability information based on time and date. The selected site for Phase II was an abandoned weigh station on I-75 NB at Rest Area 23 in Cleveland, Tennessee, 22 miles upstream of the Phase I project site. This site was selected based on the following RFP criteria:

- It is on the same direction as the Phase I site
- It is located within 35 miles of the Phase I site
- It is accessible from the same roadway
- Has controlled points of ingress and egress, and
- It's suitable for use of the proposed technology.

For Phase II only four vehicle classes were used, since it was found that the previous classification didn't perform as expected. Table 3 shows the vehicle classification used in Phase II.

Table 3: Phase II vehicle classification

Vehicle Class	Description
1	"Bobtails" – Tractor trailer truck, but no trailer
6	"Small Vehicles" – Vehicles with length between 0 and 30 feet
7	"Large Vehicles" – Vehicles with length between 30 and 90 feet
8	"Oversized Vehicles" – Vehicles with length over 90 feet

The parking availability system is designed to provide users with historical and real time availability of the parking areas. When a user selects a date in the future, the system averages three months of data for the season corresponding to the date selected. Weekend data and weekday data are processed separately and dates that are not relevant to the request are filtered out. The availability system can be accessed through the Electronic Kiosk (e-Kiosk) system, which consists of a mobile application, a SmartPark website, and an Interactive Voice Response (IVR) system. E-Kiosk does not only allow users to see current and future availability at either site, but it also allows them to reserve parking spaces up to 24 hours in advance in both parking locations. Overnight parking is not allowed in any of the two locations due to state regulations, while there is a 2 hour parking limit for the Rest Area 45 location and an 11 hour limit for the Rest Area 23 rest area. As a note, even though e-Kiosk is expected to allow for users to see future availability a description of how future availability will be estimated is not provided in the concept of operations report.

Information about parking availability on the roadway is provided to drivers by both static and Dynamic Message Signs (DMS). A static sign is placed at the entrance of each site, and a DMS is placed at least one mile upstream of both parking areas to provide information on lot parking availability. The information provided is not on the actual number of available spots. The sign provides information as described herein:

- Available: more than 4 spaces available
- Limited: 2 to 4 spaces available
- Full: 1 space available

SYSTEM OPERATIONAL ANALYSIS

Under task 1, the research team performed an evaluation of the existing implementation of the SmartPark technology at the two locations in TN. The goal of the evaluation was to measure the efficiency and effectiveness of the system. The data that was initially made available to the research team was provided by Gannett Fleming Inc. and included data collected using the three detector combinations and manual counts. While the project was in progress the research team obtained access to the online system that monitors both parking locations. The system did not provide any manual count data and only allowed partial evaluation of the system (as will be discussed in more detail next). Using these data the research team estimated three performance requirements discussed next.

Performance Requirement 1 (PR-1)

The objective of PR-1 is to evaluate all system components (e.g., detectors, data collection components, hardware, software, and communications elements). PR-1 states that "*the system shall maintain the parking area occupancy count to better than 95% accuracy*". Accuracy is dependent on the vehicle detection accuracy (i.e., how accurately do the detectors detect vehicles) and system performance (i.e., how accurate is the lot count displayed on the project Web site). To evaluate this accuracy quantity data collected by the system was compared to manual counts that represent actual conditions in the parking area. Another evaluation method is to compare the system data to the number of corrections that needed to be made to reach a 95-percent accuracy level.

Performance Requirement 2 (PR-2)

PR-2 states that "*the ingress and egress detectors must be consistent in classification with each other to a level of 95%*." Thus, the objective of PR-2 is to determine whether the used detector combination can classify vehicles similarly on entry and exit.

Performance Requirement 3 (PR-3)

Objective of PR-3 is to certify that the system is robust enough to operate undisrupted under all weather and environmental conditions since as PR-3 states "*the system shall provide parking availability information at a minimum of 99.5 percent of the time*." The system must function 24 hours per day, 7 days per week without human intervention. Outages caused by vandalism or collisions were not taken into account for the PR-3 analysis.

Data Analysis Summary

Data analysis was divided into two parts (due to data availability and differences in the vehicle classification between Phase I and II). The first part performed an operational analysis for the first site with the same data and vehicle classification used for the FHWA report prepared by Gannett Fleming Inc *(12)*. The second part of the analysis used data available through the online monitoring system which only allowed for the estimation of PR-1 as manual counts, information on vehicle classification accuracy on entry and exit, and system down times were not available.

Data Analysis: First Location/Data Provided by Gannett Fleming

For the first location data was collected and classified bases on the detector combination while data collected during any system outage was ignored. Table 4 shows the date ranges of data availability by detector combination.

Table 4: Date ranges by detector combination

Detector Combination	Period Name	Date Range
Overhead Scanner - Overhead Scanner	OO1	11/09/12–11/22/12
Overhead Scanner - Overhead Scanner	OO2	12/03/12–12/10/12
Overhead Scanner - Overhead Scanner	OO3	12/20/12–12/27/12
Overhead Scanner - Overhead Scanner	OO4	12/28/12–01/02/13
Overhead Scanner - Overhead Scanner	OO5	01/23/13–02/22/13
Light Curtain/Overhead Scanner	CO1	11/26/12–11/28/12
Light Curtain/Overhead Scanner	CO2	12/27/12–12/28/12
Light Curtain/Overhead Scanner	CO3	01/10/13–01/23/13
Light Curtain/Overhead Scanner	CO4	03/04/13–03/19/13
Side Scanner/Side Scanner	SS1	11/28/12–11/28/12
Side Scanner/Side Scanner	SS2	12/10/12–12/19/12
Side Scanner/Side Scanner	SS3	01/02/13–01/10/13
Side Scanner/Side Scanner	SS4	02/22/13–03/04/13
Side Scanner/Side Scanner	SS5	3/29/13–4/10/13

Performance Requirement 1 (PR-1)

System Performance

The system performance is based on the total system volume of vehicles in the rest area throughout the testing period and the corrections (manual adjustments) that needed to be done in the system so it was true to actual conditions. The formulas to calculate the system performance are as follows:

System error: $$E = \sum |System\ Corrections\ | \quad (1)$$

Volume: $$V = in \cdot c_{in} + eg \cdot c_{eg} \quad (2)$$

Error Rate: $$R = \frac{E}{V} \quad (3)$$

Accuracy: $$A = 1 - R \quad (4)$$

Where, in= ingrees, eg = egress, c_{in}= ingress correction factor, and c_{eg}= egress correction factor.

The formulas for the correction factors are:

$$c_{in} = 1 - \frac{in_d - in_{obs}}{in_{obs}} \quad (5)$$

$$c_{eg} = 1 - \frac{eg_d - eg_{obs}}{eg_{obs}} \quad (6)$$

Where, in_d= detected ingress, in_{obs}= observed ingress, eg_d= detected egress, and eg_{obs}= observed egress.

Vehicle Detection Accuracy

Vehicle detection accuracy accounts only for vehicles that were counted more than once or were missed by the detectors (not counted at all) and does not include misclassified vehicles. That means that even if the error within vehicle classes is bigger, only the total number of entering or exiting vehicle errors in each time period is taken into account for PR-1. The total system accuracy for all three combinations (see Table 5, Table 6 and Table 7) is greater than the 95% required accuracy required for the system to be reliable based on PR-1. The only note that needs attention is that even though the overall accuracy is satisfactory, individual classes show very high absolute value and percentage errors.

Table 5: OH-OH vehicle detection accuracy

Class	Observed Entering Vehicles	Observed Exiting Vehicles	System Entering Vehicles	System Exiting Vehicles	Absolute Entry Error	Absolute Exit Error	% Entry Error	% Exit Error
1	20	19	16	22	4	3	20%	16%
2	16	16	41	36	25	20	156%	125%
3	18	19	3	7	15	12	83%	63%
4	78	76	103	114	25	38	32%	50%
5	88	92	36	28	52	64	59%	70%
6	976	1,040	1,010	1,067	34	27	3%	3%
Total	1,196	1,262	1,209	1,274	17	14	<2%	<2%

Table 6: CUR-OH vehicle detection accuracy

Class	Observed Entering Vehicles	Observed Exiting Vehicles	System Entering Vehicles	System Exiting Vehicles	Absolute Entry Error	Absolute Exit Error	% Entry Error	% Exit Error
1	7	7	13	10	6	3	53.85%	30.00%
2	19	18	58	30	39	12	32.76%	33.33%
3	1	0	8	4	7	4	12.50%	0.00%
4	79	82	72	89	7	7	62.50%	83.15%
5	36	39	8	12	28	27	23.08%	30.77%
6	929	896	907	891	22	5	97.13%	98.09%
Total	1071	1042	1066	1036	6	3	<1%	<1%

Table 7: SID-SID vehicle detection accuracy

Class	Observed Entering Vehicles	Observed Exiting Vehicles	System Entering Vehicles	System Exiting Vehicles	Absolute Entry Error	Absolute Exit Error	% Entry Error	% Exit Error
1	8	8	10	12	2	4	25%	50%
2	21	20	45	41	24	21	114%	105%
3	28	30	2	1	26	29	93%	97%
4	70	77	117	119	47	42	67%	55%
5	62	57	7	11	55	46	89%	81%
6	1,046	1,059	1,048	1,073	2	14	0%	1%
Total	1,235	1,251	1,229	1,257	8	12	<1%	<1%

Correction Factors

Table 8 presents the correction factors for each detector combination calculated by the research team as well as the ones presented in the original report where only small differences are observed.

Table 8: Correction factors per detector combination

Detector Combination	Correction Factors	Current Study	Project Demonstration
OH-OH	Cin	0.989	0.998
	Ceg	0.991	0.993
CUR-OH	Cin	1.005	1.005
SID-SID	Cin	1.005	1.007
	Ceg	0.995	0.994

Table 9, Table 10, and Table 11 show the total detected ingresses and egresses in each time period for the three combinations. The error rate for the OH-OH combination is 0.14% (99.86% accuracy rate), for CUR-OH is 1.06% (98.94% accuracy), and for SID-SID 0.20% (99.80% accuracy).

Table 9: OH-OH performance summary

Period	Ingress	Egress	Error	Volume	Error Rate
OO1	4,544	4,561	17	9,105	0.19%
OO2	2,388	2,377	11	4,765	0.23%
OO3	1,209	1,201	8	2,410	0.33%
OO4	1,001	1,013	12	2,014	0.60%
OO5	9,594	9,598	4	19,192	0.02%
Total	14,192	14,189	52	37,486	0.14%

Table 10: CUR-OH performance summary

Period	Ingress	Egress	Error	Volume	Error Ratio
CO1	855	829	26	1,684	1.54%
CO2	247	243	4	490	0.82%
CO3	2,458	2,418	40	4,876	0.82%
CO4	558	542	16	1,100	1.45%
Total	4,118	4,032	86	8,150	1.06%

Table 11: SID-SID performance summary

Period	Ingress	Egress	Error	Volume	Error Ratio
SS1	77	73	4	150	2.67%
SS2	3,178	3,156	22	6,334	0.35%
SS3	2,668	2,652	16	5,320	0.30%
SS4	3,377	3,368	9	6,745	0.13%
SS5	5,272	5,264	8	10,536	0.08%
Total	14,495	14,440	59	29,085	0.20%

Performance Requirement 2 (PR-2)

PR-2 requires the ingress and egress detectors to equally classify vehicles with 95% accuracy. The data analysis showed, (similarly to the project demonstration report), that all detector combinations classified vehicles equally in less than 95% for most of the classes (Table 12).

Table 12: vehicle classification accuracy

Detector Combination	Ingress Accuracy	Egress Accuracy	System Accuracy
OH-OH	86.04%	83.36%	84.70%
CUR-OH	87.39%	91.36%	89.38%
SID-SID	84.94%	85.93%	85.44%

If no manual counts are available, classification consistency accuracy can be calculated through the following formulas by using ingress and egress system counts:

$$E_c = |in_c - eg_c| \tag{7}$$

$$V_c = \frac{in_c \cdot c_{in} + eg_c \cdot c_{eg}}{2} \tag{8}$$

$$R_c = \frac{E_c}{V_c} \tag{9}$$

$$A_c = 1 - R_c \tag{10}$$

Where:
E_c = class error
A_c = accuracy of classifying class “c” vehicles
R_c = error rate of classifying class “c” vehicles
V_c = class “c” volume
in_c = total ingresses of class “c” vehicles
eg_c = total ingresses of class “c” vehicles
c_{in} = ingress correction factor
c_{eg} = egress correction factor

Results of the analysis are shown in

Table 13, Table 14, and Table 15. The error in each class is the absolute difference between the manual counts and the system counts. The classification ratio shows if the detector under classified (ratio less than one) or overclassified (ratio greater than one) the vehicles. The ingress and egress accuracy was calculated by comparing the number of vehicles (by class) detected by the system to the ones counted manually. The highest accuracy rates were for large vehicles (class 6) but all the other vehicle classes do not give good results. In this project the vehicle classification accuracy was also calculated by dividing the total number of misclassified vehicles by the number of vehicles entering (or exiting) the location. The OH-OH (97.76%) and SID-SID (97.75%) combinations meet the 95% accuracy criterion but not the CUR-OH (93.46%). In the project demonstration report the correction factors were assumed to be equal to one for all cases. Results using the estimated factors differ slightly from the ones presented in FHWA report. Two (out of the three) combinations (OH-OH and SID-SID) met the 95% accuracy criterion, although this criterion is not met if a vehicle class is considered by itself (excluding vehicle class 6 for all three combination).

Table 13: OH-OH classification consistency

Vehicle Class	*Study Results*				*FHWA Report (17)*			
	E_c	V_c	R_c	A_c	E_c	V_c	R_c	A_c
1	28	238	11.76%	88.24%	31	244	12.70%	87.30%
2	33	570	5.79%	94.21%	35	578	6.06%	93.94%
3	18	72	25.00%	75.00%	18	72	25.00%	75.00%
4	158	1560	10.13%	89.87%	161	1588	10.14%	89.86%
5	133	401	33.17%	66.83%	135	407	33.17%	66.83%
6	46	15715	0.29%	99.71%	63	15965	0.39%	99.61%
Total	416	18556	2.24%	97.76%	443	18854	2.35%	97.65%

Table 14: CUR-OH classification consistency

Vehicle Class	*Study Results*				*FHWA Report (17)*			
	E_c	V_c	R_c	A_c	E_c	V_c	R_c	A_c
1	77	82	93.90%	6.10%	77	82	93.9%	6.10%
2	80	168	47.62%	52.38%	80	167	47.90%	52.10%
3	18	23	78.26%	21.74%	18	22	81.82%	18.18%
4	26	317	8.20%	91.80%	26	315	8.25%	91.75%
5	14	51	27.45%	72.55%	14	50	28.00%	72.00%
6	53	3458	1.53%	98.47%	53	3440	1.54%	98.46%
Total	268	4099	6.54%	93.46%	268	4076	6.58%	93.42%

Table 15: SID-SID classification consistency

Vehicle Class	*Study Results*				*FHWA Report (17)*			
	E_c	V_c	E_c	V_c	E_c	V_c	E_c	V_c
1	36	174	20.69%	79.31%	38	18	21.35%	78.65%
2	78	587	13.29%	86.71%	156	588	26.53%	73.47%
3	12	28	42.86%	57.14%	20	28	71.43%	28.57%
4	79	1667	4.74%	95.26%	124	1668	7.43%	92.57%
5	32	231	13.85%	86.15%	40	232	17.24%	82.76%
6	90	11858	0.76%	99.24%	166	11864	1.40%	98.60%
Total	327	14545	2.25%	97.75%	544	14864	3.74%	96.26%

Data Analysis: Both Locations Using the Data from the Online Monitoring System

The following sections present an analysis for data retrieved from the online system for the time period from 01 Jan 2016 to 03 Oct 2016 for both locations (i.e., Rest Area 23 and Rest Area 45). Based on the type of data available, only PR1 has been evaluated. Currently, the system does not tie a vehicle's ingress to its egress and thus a comparison of the classification of each truck's egress to the classification of the same truck's ingress, cannot be performed. Furthermore, the online system did not provide as means of tracking system downtime. We could make assumptions on the system downtime based on ingress or egress data unavailability, but this inference provides insufficient grounds for evaluation of PR3.

Vehicle Composition

Figure 3 and Figure 4 show the number of ingresses and egresses of vehicles by class by day of the week at both rest areas. Results show significantly fewer recorded ingress events than egress events; this discrepancy is explored later in this report. Results show that Rest Area 45 recorded a total of 112 thousand ingresses and 148 thousand egresses while Rest Area 23 recorded 35 thousand ingresses and 37 thousand egresses.

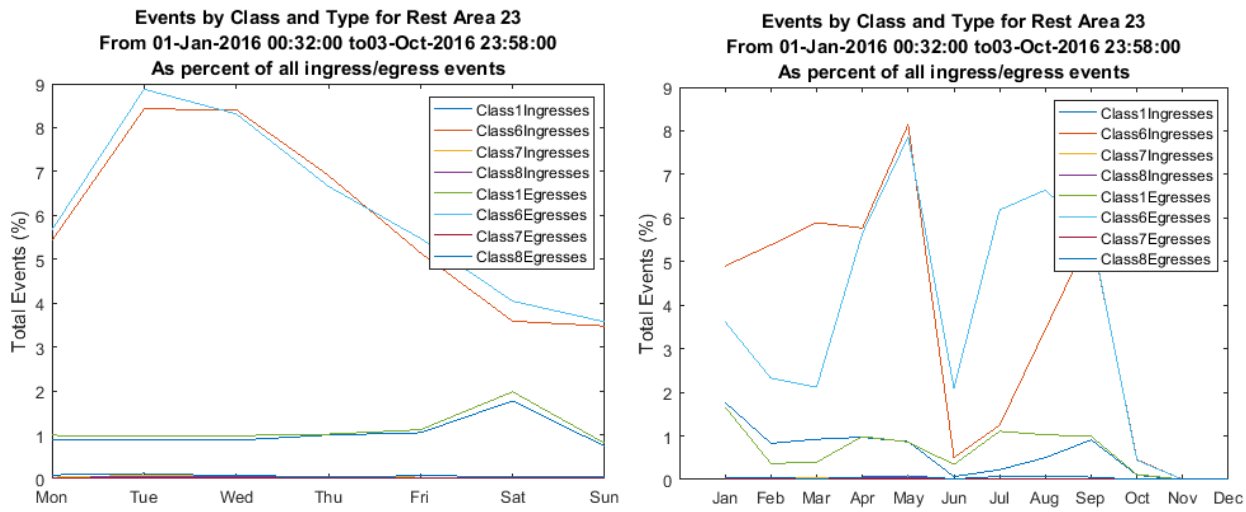

Figure 3: Activity at rest area 23 for 01 Jan 2016 to 03 Oct 2016

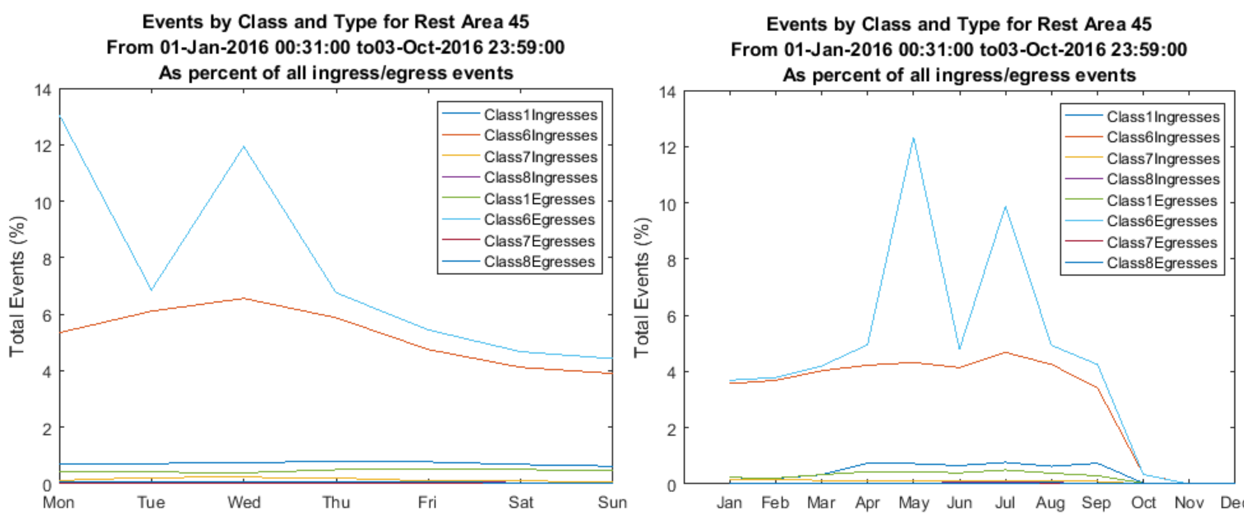

Figure 4: Activity at rest area 45 for 01 Jan 2016 to 03 Oct 2016

Hourly Lot Occupancy

Figure 5 and Figure 6 show average hourly occupancy for each rest area over the 9 months period (Jan. 2016-Oct. 2016). Note that for certain times of the day, average occupancy at Rest Area 23 exceeds capacity; this exceedance is consistent with the findings of the FHWA's 2012 *(1)* and 2015 *(18)* reports which show a severe shortage of truck parking spaces in Tennessee. For Rest Area 23, occupancy generally increases from 9:00 PM to 5:00 AM, then declines from 5:00 AM to 11:00 AM, then holds steady throughout the day. Highest lot occupancy occurs on Wednesday and Thursday; lowest occupancy occurs Friday – Sunday. A similar occupancy pattern was recorded for Rest

Area 45 although average occupancy did not exceed capacity. Highest occupancy occurs overnight on Tuesday-Thursday, and lowest occupancy occurs during afternoons and weekends.

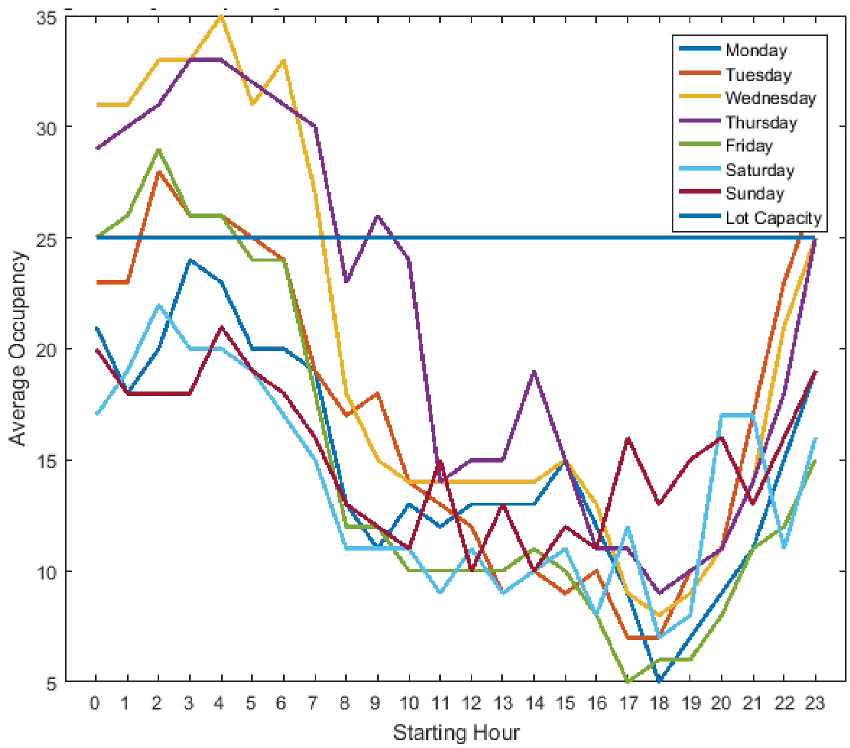

Figure 5: Average hourly occupancy for rest area 23

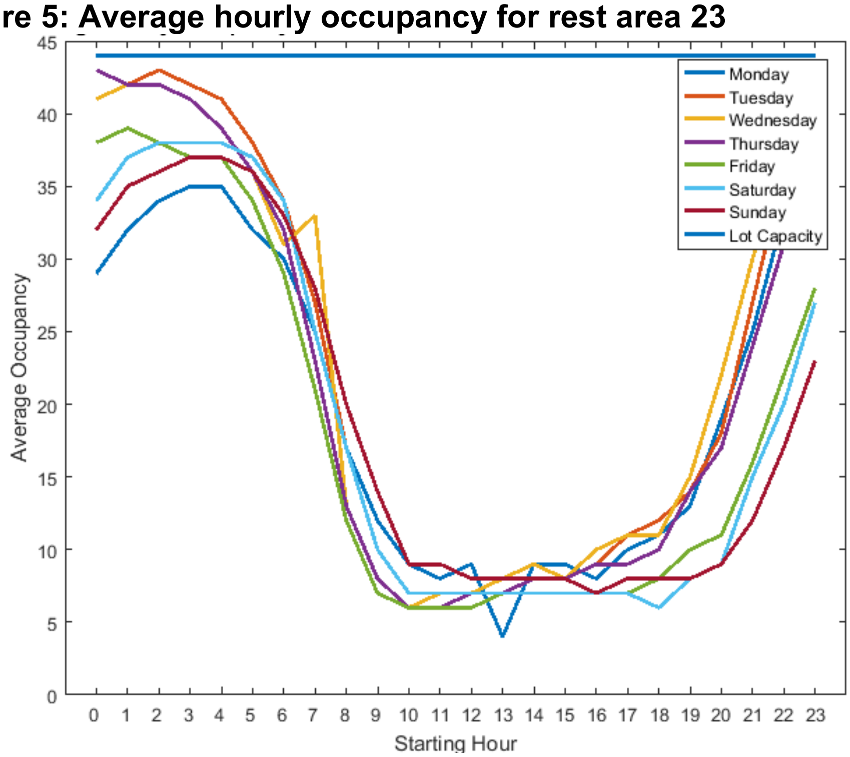

Figure 6: Average hourly occupancy for rest area 45

Performance Requirement 1 (PR-1)

Analysis of the data retrieved from the online system revealed a pattern of inconsistent occupancy counts. To evaluate the technology using this data the research team identified times of the day where a lot vehicle count could be easily verified using the static lot pictures—e.g., midday with zero occupancy or low occupancy, good lighting, and no obstructions. Analysis revealed a high level of discrepancy between the lot count shown on the website and the manual lot count taken from the still images. An example is shown in figure 7 where an egress event occurs at 9:11 AM on August 30, 2016 at Rest Area 45. The data from the website reveals that the parking lot is empty but the still image reveals at least 8 vehicles still on the lot. The research team performed the same check for three random dates for each lot and found similar discrepancies (see table 16). One possible explanation for this discrepancy may be the occurrence of simultaneous ingress/egress events where only one of the two is captured by the system. An example is shown in figure 8 where the ingress event was not captured.

Table 16: Occupancy accuracy spot checks

Date	Time	Rest Area	Occupancy from Website	Occupancy Estimate from Still Images
8/30/16	9:11 AM	45	0	8
8/30/16	4:09 PM	23	2	2
9/1/16	9:06 AM	45	5	14
9/1/16	11:52 AM	23	2	3
9/7/16	9:41 AM	45	0	14
9/7/16	2:40 PM	23	0	2

Timestamp	Event Type	Vehicle ID	Sensor Type	Sensor Mount	Class	In Use	Cls 1	Cls 6	Cls 7	Cls 8	Images
Aug 30 2016 9:11AM	Egress	625530	SCANNER	LEFT	6	0	0	0	0	0	

Figure 7: Discrepancy between lot cameras and website occupancy count

Timestamp	Event Type	Vehicle ID	Sensor Type	Sensor Mount	Class	In Use	Cls 1	Cls 6	Cls 7	Cls 8	Images
Aug 30 2016 9:23AM	Egress	625533	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:25AM	Egress	625534	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:26AM	Ingress	590331	SCANNER	RIGHT	6	1	0	1	0	0	

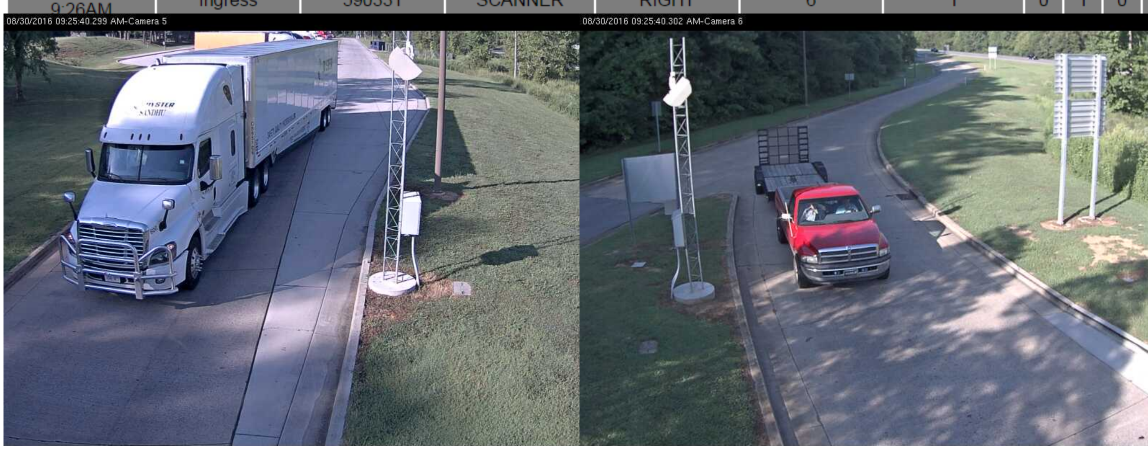

Figure 8: Simultaneous ingress/egress only one is captured

Data analysis also revealed events in which the website reported lot occupancy as zero, followed by an event of an egress—an indication of an error in the system. Figure 9, shows an example of such events where from 8:18AM through 9:25AM four trucks egress the facility when the facility is empty and no record of an ingress truck exists.

Timestamp	Event Type	Vehicle ID	Sensor Type	Sensor Mount	Class	In Use	Cls 1	Cls 6	Cls 7	Cls 8	Images
Aug 30 2016 9:02AM	Egress	625527	SCANNER	LEFT	1	0	0	0	0	0	
Aug 30 2016 9:02AM	Ingress	590328	SCANNER	RIGHT	6	1	0	1	0	0	
Aug 30 2016 9:09AM	Egress	625529	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:11AM	Egress	625530	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:11AM	Ingress	590329	SCANNER	RIGHT	6	1	0	1	0	0	
Aug 30 2016 9:18AM	Egress	625531	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:21AM	Egress	625532	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:23AM	Egress	625533	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:25AM	Egress	625534	SCANNER	LEFT	6	0	0	0	0	0	
Aug 30 2016 9:26AM	Ingress	590331	SCANNER	RIGHT	6	1	0	1	0	0	
Aug 30 2016 9:27AM	Ingress	590332	SCANNER	RIGHT	6	2	0	2	0	0	
Aug 30 2016 9:30AM	Ingress	590333	SCANNER	RIGHT	1	3	1	2	0	0	
Aug 30 2016 9:31AM	Egress	625535	SCANNER	LEFT	6	2	1	1	0	0	
Aug 30 2016 9:33AM	Ingress	590334	SCANNER	RIGHT	6	3	1	2	0	0	
Aug 30 2016 9:34AM	Ingress	590335	SCANNER	RIGHT	6	4	1	3	0	0	
Aug 30 2016 9:34AM	Ingress	590336	SCANNER	RIGHT	6	5	1	4	0	0	

Figure 9: Egress while lot occupancy is zero

A summary of these errors (i.e., the total number of times a vehicle egressed from empty lot) is shown in Figure 10 for both rest areas (for data from 01/01/16 through 10/03/16 for each rest area). The x-axis shows the errors by month, day of the week and time of day, and the y-axis the percent error calculated as:

$$\%\ error = \frac{number\ of\ egresses\ from\ empty\ lot}{total\ number\ of\ events}$$

Figure 11 shows the same data, with percent errors calculated a little differently—we compare the number of errors to the number of egresses only, rather than the total number of events. This figure shows the percent error calculated as:

$$\%\ error = \frac{number\ of\ egresses\ from\ empty\ lot}{total\ number\ egresses}$$

Results of this analysis suggest a hardware problem at both rest areas. Rest Area 23 appears to have had a problem with the ingress sensor from June through mid-August. Rest Area 45 appears to have had a problem with the ingress sensor beginning September, 2016. Data sets taken from this period (and shown in Appendix B) show long periods of time with many egress events and no ingress events, suggesting a problem with the ingress sensor.

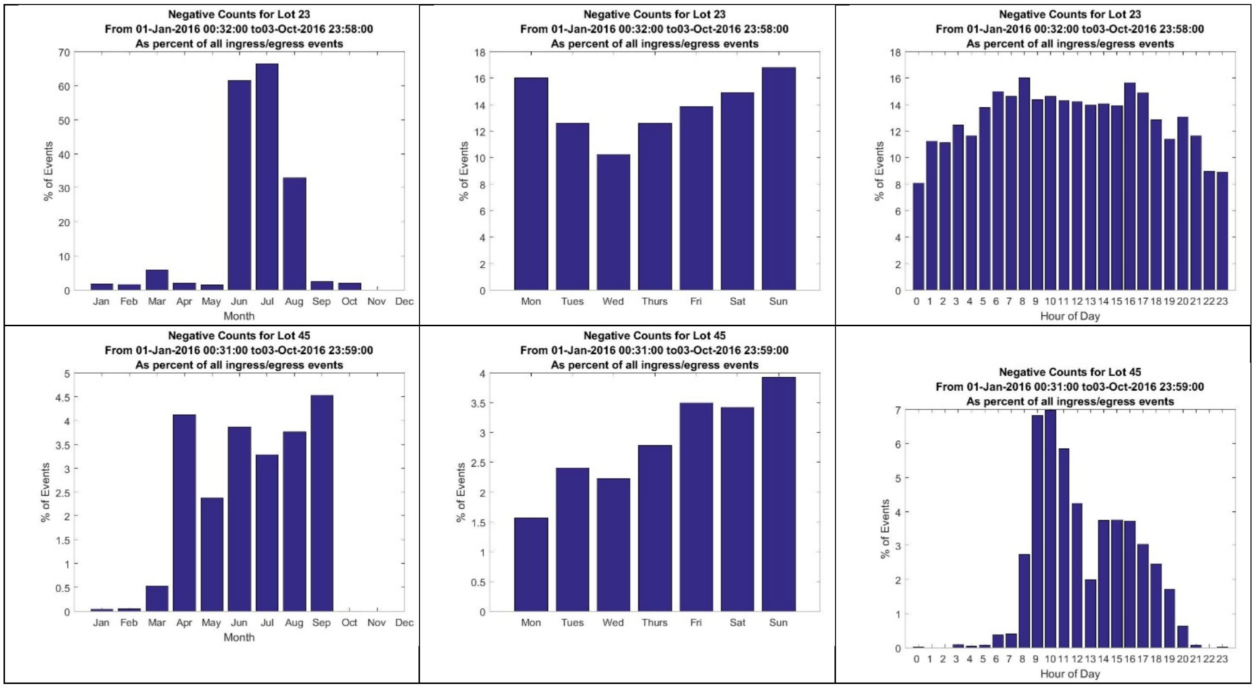

Figure 10: Egress errors by lot, as a percent of total events

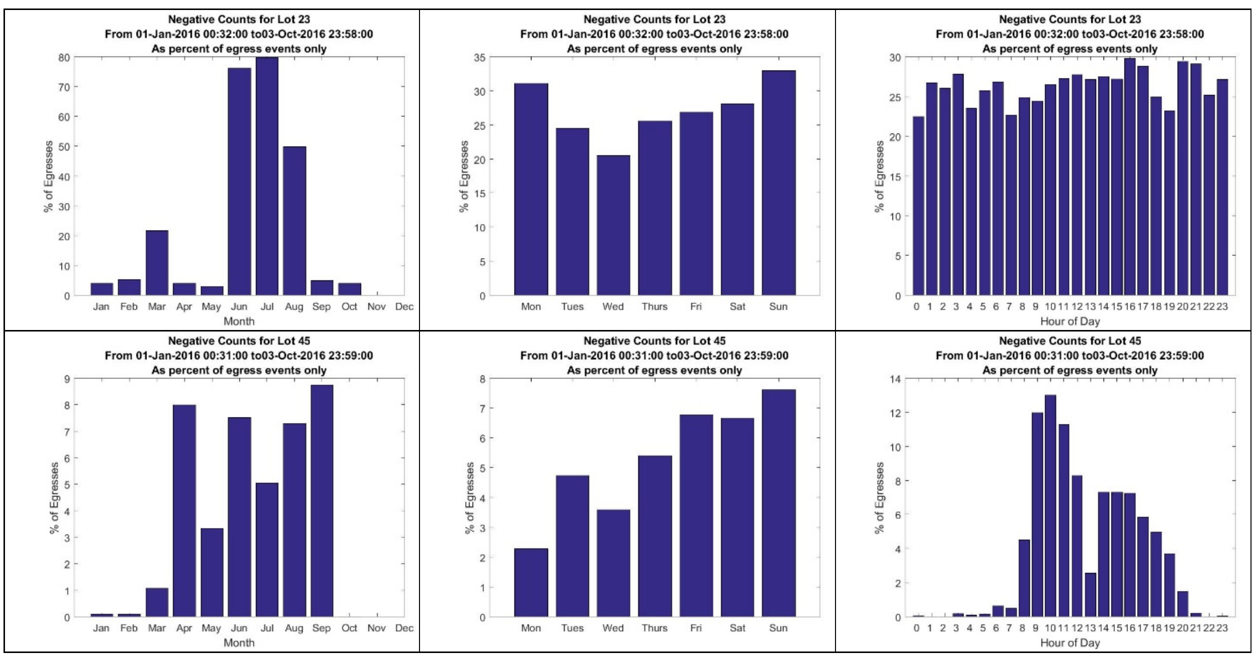

Figure 11: Egress errors by lot, as a percent of egress events only

TASK 2: SMARTPARK SURVEYS

Three surveys were developed as part of this task. The objective of the first survey was to collect information on level of satisfaction among the users of public rest areas (Rest Area 45 and Rest Area 23), on their experience as well as their input on possible improvements or current drawbacks of available SmartPark technology for parking. The second survey was designed to gather information on truck parking from the trucking industry professionals. The third survey was prepared to collect information on how private rest area owners design and manage private rest areas to better understand the willingness of these owners to adopt the technology and participate in public private partnerships to finance the implementation and maintenance of the technology. Questionnaire of all three surveys are presented in Appendix A1 through 3. The goal of the user's survey was to obtain a comprehensive understanding of the functionality of the current SmartPark system as well as major and minor improvements that should be implemented. For instance, the survey was designed to provide data that can be used to determine key impact factors for SmartPark as they relate to different kinds of locations, geometric conditions, type of operator (long vs short haul, owner-operator vs small business vs large motor carriers) and operating environments. The user survey was performed on Monday, Sept. 12 and Tuesday, Sept. 13 2016 to users at the Rest Area 45 and Rest Area 23 between 7am and 5pm. In the next section we summarize the findings of the user's survey. The Trucking Industry Professional's survey and the Private Rest Area Owner's survey have not yet been conducted.

Users Survey Results

A total of 164 survey responses were collected from both sites with a higher number of responses (approximately 68%) collected from rest area at Rest Area 45 (Table 17). This is expected as the capacity of Rest Area 45 is higher. Results for each survey question are shown graphically in Appendix C and summarized next.

Table 17: User survey response summary

Date	Location	
	Rest Area 23	Rest Area 45
Mon, 12-Sept	33	36
Tues, 13-Sept	18	77

Table 18 shows a pivot table between the average length of haul (Question 3) and the difficulty of finding parking (Questions 7, 9, and 10). As expected, drivers who stay on the road longer tend to take longer breaks (Question 7), and tend to have more trouble finding safe parking (Question 9). This table also shows consistency between responses to Questions 9 and 10: drivers who "never" have difficulty finding safe parking in Question 9 also "never" find it difficult to park in Question 10.

Table 18: Average length of haul vs rest duration and difficulty finding parking

Average Length of Haul	Question 7: Rest duration				Question 9: Frequency of difficulty finding parking				Question 10: Time of day having trouble to find parking				
	< 2 hours	2-4 hours	4-6 hours	6+ hours	Never	Rarely	Occasionally	Regularly	6AM-9AM	9AM-2PM	2PM-6PM	6PM-6AM	Never

Local	5	0	1	0	2	0	1	3	0	0	1	2	2
Regional	41	1	0	28	13	10	12	34	4	2	2	47	13
Inter-Regional	25	2	2	10	1	3	13	22	1	1	2	34	1
Long-Haul	17	4	5	19	4	1	15	22	1	2	5	34	1

The largest group of respondents (Figure 20) were regional haulers traveling between Knoxville, Chattanooga, and Atlanta. Long haul and inter-regional haulers comprise of 52% of the total surveyed response. Local haulers do not use interstates as observed in the collected survey data. Most drivers operate "Straight Trucks" or "5-Axle Flatbed" (Figure 21). Approximately 60% users fall under the category of dedicated drivers (Figure 22) which also correlates to the higher number of Regional and Interregional drivers (Figure 20). Over 90% of the drivers are team drivers (Figure 23). Since the survey was based on primarily interstate travel regional and interregional travels are expected confirming to long haul. 55% of the users reported less than two hours of stay at the both locations (Figure 24). Two primary reasons could be the fact that surveys were conducted between 7am through 5pm, and during these time periods, typically drivers take a quick break and not stay longer as the typical work hours are mostly during the day. However, second highest category is six plus hours of stay representing overnight drivers who responded to questionnaires in the AM.

76% of the surveyed drivers use sleeper birth which reinforces the need for smarter truck parking, and the impetus for this project (Figure 25). Because most drivers prefer to rest in the truck's sleeper berth, reliable access to safe truck parking is expected to remain important factor for highway safety. Long haul drivers have increased need of overnight parking (Figure 26, Figure 27), and have the highest difficulty in finding safe parking. 52% of the drivers indicated that they stop in these two locations sometimes where as 31% of the drivers indicated that they do stop frequently (Figure 28). Considering higher percentage of regional and inter-regional drivers of survey respondents it would be expected that they stop either frequently or sometimes on these two locations for parking. 65% of the users were familiar about advanced truck parking information as the truck parking availability information is also displayed on dynamic message signs along I-75 (Figure 29). When asked how they knew about advanced truck parking availability (Figure 30), many users indicated "Other" or "No Response". "Other" has possibility of knowing from the dynamic message sings along I-75. 5% of respondents indicated they had heard about the SmartPark lots from their employers. 73% of users indicated that they are familiar with the signs along I-75 (Figure 31).

Figure 32 summarizes response to the question if the users find the messages displayed on dynamic message signs are easy to read and understand. 74% of users indicated that they are familiar with the SmartPark sites had seen and understood the displayed message. Figure 33 shows if the users knew of a mobile phone application (app) on truck parking availability. While many respondents had seen the VMS or were aware of the SmartPark rest areas, far fewer were familiar with the SmartPark app.

Survey results revealed that very few respondents have used the SmartPark app (Figure 34). This implies that even drivers who are aware of the app (28%) are hesitant to use it. Results of Figure 34 suggest that the SmartPark app can be further improved for wider use and also sending availability to other apps such as “ParkMyTruck” could be considered as an alternative. Only 38% of the app users responded that the information available in the app is easier to understand (Figure 35). A review of the data shown in Figure 34 and Figure 35 indicated the onset of survey fatigue (a condition in which correspondents become disinterested in the survey, and the quality of responses degrades). Based on the results shown in Figure 34 it was expected that the same number of respondents indicating they had not used the app or where not aware of it (92%) would respond “no response” instead of the actual 31%. Only 1/3 of respondents answered the question on the accuracy of the information displayed on the app with 78% of those responding (Figure 36) indicating that the app is correct “Always” or “Most of the time.”

When asked on their willingness to pay to reserve a spot in advance (Figure 37) 75% responded that they are unwilling to pay to reserve a spot. This high percentage may be explained by the trip type taken by the interviewees (i.e., day time drivers who typically stop less than two hours during the trip). It would be useful (as a future research direction) to perform a survey during night time (although this would require a significant effort to establish a safe environment and prior notification distributed to the drivers). On the follow-up question of how much users are willing to pay to reserve a parking spot in advance a high number of respondents (Figure 38) refused to answer this question.

A very small number of respondents indicated that they had stopped due to HOS regulations (Figure 39) which may be attributed to the time of day the surveys were conducted (i.e., daytime). At both locations over 50% of users responded that they feel safe (Figure 40) although respondents at Rest Area 23 roughly 40% responded that they do not feel safer at this location compared to others. 77% of users stated that their privacy is unaffected by the presence of security cameras (Figure 41). Rest Area 45 is well-developed; its amenities include restrooms, a visitor’s center, picnic tables, and vending machines which can increase the feeling of safety (as opposed to rest area at Rest Area 23, that does not have any amenities). To that end, the question on what amenities the users would like to have (Figure 42) resulted in differences in responses to several different categories: restaurant, rest rooms, showers, and truck parking. This question was also used as a check for survey efficacy. In theory, every respondent should have indicated a desire for truck parking at a truck stop; instead, only 68% of Monday’s respondents and 83% of Tuesday’s respondents indicated a desire for this basic feature. This inconsistency may be another indication of survey fatigue. Approximately, 80% of respondents left no response, or indicated “$5,” and 4-6% indicated “$15” when asked on their willingness to pay for full amenities (Figure 43). For partial amenities, most of the users indicated that they are unwilling to pay or pay less than $5 (Figure 44 and Figure 45). What is surprising though is the significant percentage of respondents (13%) indicating a willingness to pay for Fuel/Store; amenities that are usually provided free of cost.

The final survey question was a free-response question on the reasons for parking on the ramp when parking was available on site with only 19% response rate. Responses indicate issues with the facility (e.g., oversize load) and safety/security (e.g., trouble fitting, be alone, avoid cameras).

Table 19: Reasons for parking on ramps

Reason	# Responses
Trouble fitting in space OR other drivers have parked poorly	8
HOS Regulation	7
Don't want to pay	5
Oversized Load	4
Breakdown	3
To Be Alone	2
Dynamic Message Sign is incorrect	1
Avoid cameras	1

TASK 3: REVIEW OF FUTURE SMARTPARK LOCATIONS AND BUSINESS PLAN FOR TENNESSEE AND MARKET VIABILITY

Potential Future SmartPark Locations

In this section, potential SmartPark locations are examined for the case that TDOT plans to expand the existing system to other rest areas in the state. Tennessee has 47 public rest area locations and 148 private rest area locations widespread throughout the state on all interstates passing through the state *(20)*. Rest areas that could be selected for future SmartPark deployment need to have the characteristics set on projects' RFP. These criteria are as follows:

1. Another location exists that could be used to connect the selected location (representing one system)

2. Both locations should be in same direction, be accessible from the same roadway and within 35 miles from each other.

Based on these criteria, eleven (11) locations were identified by the research team in the State of TN and are listed in Table 20**.** The table shows pairs of candidate locations, the distance between each location and the truck flow observed in the adjacent roadway as measured from the TN statewide model. Note that rest areas 13, 14 and 15 can be used to form a three location system while area 13 is the one with the largest adjacent truck flow.

Table 20: Potential future SmartPark locations

Rest Area ID	Coordinates		Interstate	Distance between locations	Adjacent link Truck Flow
	X	Y			
13	-86.888	35.6793	I-65	24 miles	13225
14	-86.881	35.3293			3003
14	-86.881	35.3293	I-65	20 miles	3003
15	-86.878	35.0354			3037
24	-85.559	35.0248	I-24	12 miles	9685
26	-85.399	34.9935			9757
30	-85.055	35.1	I-75	3 miles	7848
31	-85.026	35.1272			7720
35	-84.945	35.9463	I-40	12 miles	5071
37	-84.781	35.9			5297
41	-83.322	36.0347	I-40	17 miles	3402
42	-83.159	35.8191			4154

Other required characteristics of potential SmartPark locations include:

- Recently reconstructed site with easily accessible truck parking spaces;
- Single points of ingress and egress;
- Separated truck and car parking areas;
- Ample lighting for nighttime operations.

Due to time and budget constraints on-site inspection of these eleven locations was not performed. Google Earth was used to address this issue and to inspect each location. Locations 41 and 42 as can be seen in Figure 12 and Figure 13 meet all the above criteria. Location 41 is a rest area on I-40 in Jefferson County (East of Knoxville) and location 42 is a TN State Welcome Center in Cosby County.

Figure 12: Rest area 41, Jefferson County I-40 West rest area

Figure 13: Rest area 42, TN State Welcome Center

Table 21 summarizes the required characteristics met in each one of the candidate locations. Five locations (i.e., 13, 14, 30, 31, 37) have many similarities (i.e., no facilities, no lighting, no space delineation) with the area selected in Phase II of the SmartPark pilot project. To utilize these locations previous reconstruction should be done as with the one in I-75 NB Rest Area 23 location.

Table 21: Candidate locations characteristics

Rest Area ID	**13**	**14**	**15**	**24**	**26**	**30**	**31**	**35**	**37**	**41**	**42**
Recently reconstructed site	-	-	x	-	x	-	-	-	-	x	x
Easily accessible truck parking spaces	-	-	x	x	x	-	-	x	-	x	x
Single points of ingress and egress	x	x	x	x	x	x	x	-	x	x	x
Separated truck and car parking areas	-	-	x	x	x	-	-	-	-	x	x
Ample lighting for nighttime operations	-	-	x	x	x	-	-	x	-	x	x

New Technologies Used for Intelligent Truck Parking

The concept of intelligent truck parking is relatively new but researchers are looking for ways to optimize the technology as commercial vehicle driver safety is correlated to available truck parking. In Europe, this concept seems to be more advanced at the time since different technologies have been used, for longer period of time and in more locations. In this section of the report, technologies that have mainly been used in Europe are presented for deployment consideration in future SmartPark locations.

In 2014 the pilot project of Intelligent Controlled Compact Parking (Compact Parking) started in a rest area in A3 motorway in Germany*(21)*. Controlled Parking was developed by the German Federal Highway Research Institute. When a driver enters a truck parking facility can decide in which row to park the truck based on the latest possible departure time offered on each row displayed on VMS and his planned departure time. An update of the departure times on the VMS is scheduled every 15 minutes and if a row is fully occupied the corresponding departure time will be transferred to the neighboring row that is still available for the truck drivers. An example of Controlled Parking and latest departure estimation is shown Figure 14.

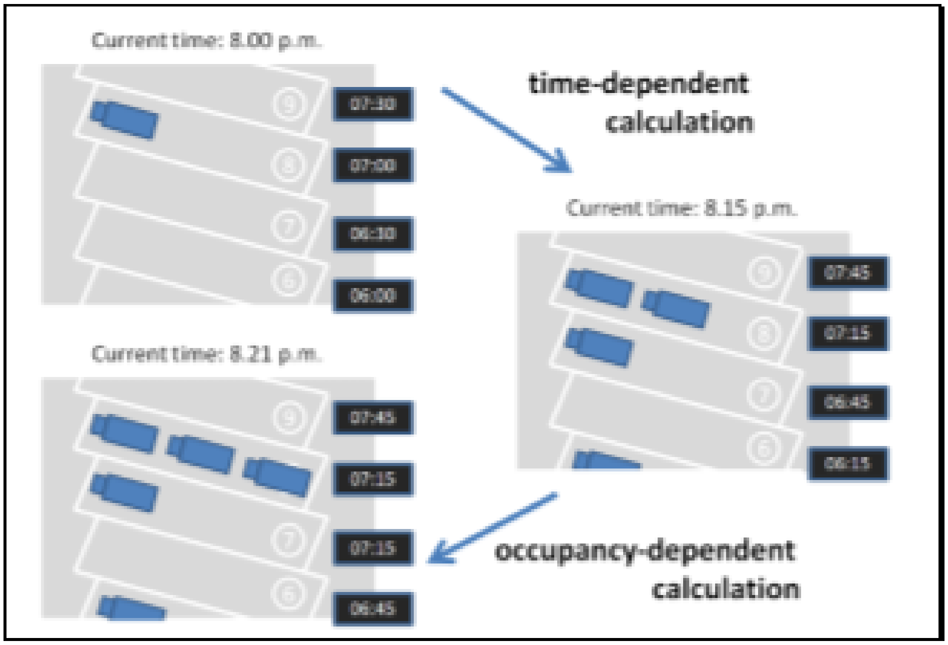

Figure 14: Controlled parking time calculation *(21)*

Information about the system (up to date occupation information and available departure times) is provided to the drivers via the Internet. This allows users to check parking availability in advance and in case a driver changes the planned departure time, he can check the anticipated departure time of the vehicles that are parked in front or behind him.

The system also accounts for drivers who park in the wrong row and makes real time corrections with a control procedure. Some situations that it accounts for as stated in the projects research paper are presented herein:

- Scenario 1: The vehicle is parked in an empty row in the first position. In case a later departure time is shown in this row no system malfunction is occurred.
- Scenario 2: The truck is parked in an already partially occupied row. When the vehicles in the row have a later departure time, it is the drivers own fault that they are restraint from leaving the rest area at the planned time.
- Scenario 3: The truck is parked in a row with an earlier departure time. Other arriving vehicles, having an earlier departure time, will be delayed in leaving the rest area. Depending on the occupancy they might reverse out of the parking row or use empty neighbored parking rows to circuit the wrongly parked vehicle. If necessary the wrongly parked vehicle has to leave the rest area earlier.
- Scenario 4: The truck is parked in the last parking position in a partially occupied row. This behavior is not critical if the other vehicles in the parking row have an

earlier departure time. Otherwise, there is a self-inflicted delayed departure time for the improperly parked vehicle.

Besides VMS, a detection technology is used in this type of intelligent truck parking that measures the remaining length per row (e.g. with laser-radar detection). High accuracy is not required for the detection technology, because the control procedure just needs information on whether at least one truck can park in a row or not. If the remaining length is less than 65 ft/20m, the departure time of that row will be shown on the neighbored VMS row, if still empty. If a single detector fails, this row is treated as fully occupied. The departure time will be displayed in the adjacent row of the defective detection and both rows can be used for parking (i.e. failure does not result in reduced parking capacity). An earlier technology was using a barrier at terminal's entrance where drivers could enter their departure time and the length of the vehicle and then would be assigned based on the input data to a free parking row taking into account the departure times and locations of the already parked vehicles.

(16) proposed an improvement for the existing Hungarian Intelligent Truck Parking system in use. They noticed that depending on how far from the rest area a VMS is, the information it provides to the driver might not be accurate when he arrives at the destination. That is, when the driver was passing by the VMS there were available spaces but all spaces were occupied in the time it took him to arrive.

The current system does not support pre-booking and scope of their proposed methodology is to develop a parking management system that allows space booking. For this system it is necessary to have historical occupancy data and also monitor actual traffic and meteorological parameters that are needed to reliable forecast system occupancy. Meteorological and traffic parameters are measured in meteorological and traffic stations respectively and transmitted to the central data processing unit periodically.

Measured data are updated when a reservation occurs and transferred to the information processing center through the telecommunication subsystem. From there, users can have access to reach them and can make decisions about planned route and parking.

Users get information on parking availability either from On Board Units (OBU), smartphones, via the Internet or by VMS located 2-3 km from the rest area to reduce the time needed to traverse to the parking spot. Short-, medium- and long-term forecast is available for users and they can pre-book parking spaces with any of the available technology (OBUs, Internet, Smartphone apps). OBUs can give information about free parking spaces and available services by RDS-TMC (Radio Data Systems - Traffic Message Channel), DAB (Digital Audio Broadcasting) and Internet.

Capital Funding Opportunities

The Fixing America's Surface Transportation Act (or the FAST Act) was enacted on December 4, 2015. It is a five-year bill that sets FMCSA authorization funding levels through FY 2020. The FAST Act authorizes programs to improve the Nation's surface transportation infrastructure and enhance safety for highways, public transportation, motor carrier, hazardous materials, and passenger rail. The FAST Act authorizes $305 billion over fiscal years 2016 through 2020 for highway, highway and motor vehicle safety, public transportation, motor carrier safety, hazardous materials safety, rail, and research, technology, and statistics programs *(22)*. The seven programs under FAST Act and their apportionments for the state of TN are shown in Table 22.

Table 22: FAST Act apportionments in TN (US dollars in millions)

Program Name	2016	2017	2018	2019	2020	Total
1. National Highway Performance Program	$492	$502	$512	$523	$533	$2,562
2.Surface Transportation Block Grant Program	$245	$251	$256	$261	$267	$1,280
3.Highway Safety Improvement Program	$49	$50	$51	$52	$53	$256
4. Railway- Highway Crossing Program	$5	$5	$5	$5	$5	$25
5. Congestion Mitigation and Air Quality Improvement Program	$37	$38	$38	$39	$40	$192
6. Metropolitan Planning	$5	$5	$5	$5	$5	$25
7.The new National Highway Freight Program	$25	$24	$26	$29	$32	$135
Total Funding Available	$857	$875	$894	$914	$936	$4,476

Of the programs listed in Table 22, programs 1, 2, and 7 could provide funding to support a Smart-Park program in TN. This statement is based on the eligible activities as described in each program. Purpose of the **National Highway Performance Program** (NHPP) is to provide support for the condition and performance of the **National Highway System** (NHS); to provide support for the construction of new facilities on the NHS; and to ensure that investments of Federal-aid funds in highway construction are directed to support progress toward the achievement of performance targets established in a State's asset management plan for the NHS. The eligible activities for the Smart-Park project as presented in the NHPP Implementation Guide are *(23)*:

i. Highway safety improvements on the NHS. The term "Safety improvement project" is defined in 23 U.S.C. 101(a).

j. Capital and operating costs for traffic and traveler information monitoring, management, and control facilities and programs. The project or activity must be associated with an NHS facility.

l. Infrastructure-based intelligent transportation systems capital improvements, including the installation of vehicle-to-infrastructure communication equipment. The project or activity must be associated with an NHS facility.

The FAST Act converts the long-standing Surface Transportation Program (STP) into the Surface Transportation Block Grant Program (STBG) acknowledging that this program has the most flexible eligibilities among all Federal-aid highway programs. The STBG promotes flexibility in State and local transportation decisions and provides flexible funding to best address State and local transportation needs. STBG funds are available for obligation for a period of 3 years after the last day of the fiscal year for which the funds are authorized. Thus, funds are available for obligation for up to 4 years *(24)*. Under the eligible projects and activities, it is the construction of infrastructure-based intelligent transportation systems capital improvements, including the installation of vehicle-to-infrastructure communication equipment and truck parking facilities eligible under Section 1401 of MAP-21. Section 1401 (Jason's Law) makes eligible for Federal funding the construction of safety rest areas, CMV parking facilities, electric vehicle, and natural gas vehicle infrastructure.

The National Highway Freight Network (NHFP) consists of the Primary Highway Freight System (PHFS), Critical Rural Freight Corridors, Critical Urban Freight Corridors, and those portions of the Interstate System that are not part of the PHFS. NHFP funds must contribute to the efficient movement of freight on the NHFN and be identified in a freight investment plan included in the State's freight plan (required in FY 2018 and beyond) *(25)*. Eligible uses of program funds as stated in the program's guide and can be used for the proposed project are:

- Intelligent transportation systems and other technology to improve the flow of freight, including intelligent freight transportation systems.
- Truck parking facilities eligible for funding under section 1401 (Jason's Law) of MAP–21.
- Real-time traffic, truck parking, roadway condition, and multimodal transportation information systems.

CONCLUSIONS AND RECOMMENDATIONS

This report summarized the research activities and products performed to evaluate the efficiency and effectiveness of the existing implementation of the SmartPark technology at two locations in TN, and a survey of SmartPark users. The report also presented a first business plan for a Tennessee SmartPark Program that included possible funding sources and a review of potential future installation sites where this technology could be deployed. Evaluation of the existing system focused on accuracy of occupancy (i.e., vehicle detection accuracy), classification accuracy at the ingress and egress, and operational robustness. Analysis using the available data from the existing system revealed a pattern of inconsistent occupancy counts and a high level of discrepancy between lot counts via the system and manual lot counts taken from still images. Data analysis also revealed events in which the website reported zero occupancy followed by an event of an egress, which suggests a hardware problem.

Based on the data analysis and considering the cost (capital investment and maintenance/operation) of the proposed system the research team recommends that alternative technologies are considered that utilize cameras and artificial intelligence to identify trucks at the parking lot and provide good accuracy at a reduced cost (when compared to the existing system). Some examples of other technologies include image processing and connected devices with any myriad of tracking options in the internet of things (IoT) where the need for installing tracking technology is minimum along with less capital and maintenance cost of the technology. The research team also identified several locations for the installation and testing of such systems. The research team highly recommends that interstate parking capacity analysis (utilizing various data sources and surveys of the trucking community) in the State of Tennessee (that accounts for parking capacity and truck traffic flows in neighboring states) is also performed annually to support these efforts of providing adequate parking capacity.

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APPENDIX A: SURVEYS

A1: TRUCK DRIVER SURVEY

1. **Which of the following best describes your employment?**
   - Employee Driver
   - Owner-Operator (O-O) with own authority
   - Independent Contractor (I-C) leased to a motor carrier
2. **Which sector best describes your operation?**
   - Truckload
   - Less-than-Truckload
   - Specialized, Flatbed
   - Specialized, Tanker
   - Express / Parcel Service
   - Intermodal Drayage
   - Other
3. **What is your average length of haul?**
   - Local (less than 100 miles per trip)
   - Regional (100-599 miles per trip)
   - Inter-Regional (600-999 miles per trip)
   - Long-Haul (1,000+ miles per trip)
4. **What is the primary vehicle configuration that you typically operate?**
   - 5-axle Dry Van
   - 5-axle Refrigerated Trailer
   - 5-axle Flatbed
   - 5-axle Tanker
   - Straight Truck
   - Longer Combination Vehicles (Doubles Triples, etc.)
   - Other
5. **Do you primarily drive dedicated, regularly scheduled runs?**
   - Yes
   - No
6. **Are you a team driver?**
   - Yes
   - No
7. **How long do you usually stay at a truck stop?**
   - Less than 2 hours
   - 2-4 hours
   - 4-6 hours
   - 6+ hours
8. **For every 10 required 10-hour breaks, how many do you rest in the sleeper berth, in a motel, or other location?**
   - Sleeper Berth:
   - Motel:
   - Other Location:
9. **How often have you experienced difficulty in finding safe parking location in the past year?**
   - Never
   - Rarely (once or twice a year but less than once a month)
   - Occasionally (one or more times a month but less than once a week)
   - Regularly (one or more times a week)
10. **Which time of day do you usually experienced most difficulty in finding safe parking?**
    - 6AM-9AM
    - 9AM-2PM
    - 2PM-6PM
    - 6PM-6AM
    - No difficulty finding safe parking

11. **Do you stop frequently here?**
    - Yes
    - It is the first time
    - Sometimes
12. **Do you know that there are two locations in TN that provide truck parking availability information 24/7?**
    - Yes
    - No
13. **If yes in 12, how did you find out?**
    - Word of mouth
    - Internet/Newspaper
    - Employer
    - Other
14. **If yes in 12, did you see the truck parking information signs on I-75?**
    - Yes
    - No
15. **If you answered "yes" on question 14, can you understand the information shown on the truck parking information signs?**
    - Yes
    - No
16. **If yes in 12, do you know that there is an app for parking availability and that you can reserve a spot?**
    - Yes
    - No
17. **If yes in 12, have you used this app in the past?**
    - Yes
    - No
18. **If you answered "yes" on question 17, can you understand the information shown on the truck parking information app?**
    - Yes
    - No
19. **If yes on question 17, how accurate would you say it is?**
    - Always
    - Rarely
    - Most of the times
    - Never
20. **Would you be willing to pay to reserve a spot?**
    - Yes
    - No
21. **How much would you be willing to pay to reserve a spot?**
    - $5
    - $15
    - $10
    - Other (please list maximum)
22. **Did you stop today because of HOS regulation?**
    - Yes
    - No
23. **Do you feel safer in this location vs other locations?**
    - Yes
    - No
24. **Do you feel your privacy is affected by the presence of cameras in the location**
    - Yes
    - No
25. **What amenities would you use in a truck rest area (select any that apply)?**
    - Fuel
    - Restaurants
    - Store
    - Rest Rooms
    - Showers
    - Electrification/Shore Power/Plug in
    - Laundry Room
    - Maintenance Services
    - Vending Machines
    - Exercise Room
    - Wi-Fi
    - Truck Parking
    - Other (please specify)

26. How much would you be willing to pay for these amenities?

a) Full amenities:
- o $5
- o $10
- o $15
- o Other (please list maximum)

b) Partial amenities (Restaurants/Rest Rooms/Showers/Laundry Room):
- o $5
- o $10
- o $15
- o Other (please list maximum)

c) Partial amenities (Fuel/Store):
- o $5
- o $10
- o $15
- o Other (please list maximum)

27. If there are any spots available at the rest area, what would be the reasons for you to park at the ramp?

A2: TRUCKING INDUSTRY PROFESSIONALS SURVEY

1. **Do your drivers deliver goods in more than one state and have a need to park their truck to get required sleep?**
   - Yes
   - No

2. **Have your truck drivers experienced a problem finding a safe location to park their truck when required rest or sleep was needed?**
   - Yes
   - No

3. **Do you schedule your driver routes based on available truck parking?**
   - Yes
   - No

4. **What percentage of your drivers regularly need a place to park their truck to get required rest?**
   - 0-25%
   - 25-50%
   - 50-75%
   - 75-100%

5. **Are you aware of the Smart park locations in the country and the app for it?**
   - Yes
   - No

6. **If yes, do you advice your drivers to use these locations?**
   - Yes
   - No

7. **If yes, do you know that you can reserve a spot through an app in these locations?**
   - Yes
   - No

8. **Do you think your driver's sense of safety is affected in Smart park locations?**
   - Yes
   - No

9. **Do you think your driver's sense of privacy is affected in Smart park locations?**
   - Yes
   - No

10. **Do you think the use of those locations could benefit your company?**
    - Yes
    - No

11. **Would you subsidize any cost related for usage of the facility (including reservation costs)?**
    - Yes
    - No

A3: PRIVATE REST AREA OWNERS SURVEY

1. **Do you currently use any of the following technologies:**
    a. Monitoring cameras (for current occupancy)
    b. Online reservation system
    c. Online reservation system with cell phone application
    d. Prediction tool of future park occupancy
    e. Other (please specify)

2. **How likely are you to partner in a PPP to develop the infrastructure for a smart park**
    a. Not likely at all
    b. Somewhat likely
    c. Likely
    d. More likely
    e. Definitely

3. **If you answered yes in question 3 would you be willing to provide matching funds (capital and/or operational/maintenance)**
    a. Not likely at all
    b. Somewhat likely
    c. Likely
    d. More likely
    e. Definitely

4. **What are in your opinion the influential factors that attract truckers to your location**
    a. Fuel
    b. Restaurants
    c. Store
    d. Rest Rooms
    e. Showers
    f. Electrification/Shore Power/Plug in
    g. Laundry Room
    h. Maintenance Services
    i. Vending Machines
    j. Exercise Room
    k. Wi-Fi
    l. Truck Parking
    m. Other (please specify)

5. **Do you think any of the following technologies could benefit your company (please circle the ones that will)**
    a. Vehicle detection technology (entering/exiting facility)
    b. Computer server to store and process data
    c. Closed circuit television (CCTV) cameras

Appendix B: Sensor Malfunction

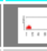
Timestamp	Event Type	Vehicle ID	Sensor Type	Sensor Mount	Class	In Use	Cls 1	Cls 6	Cls 7	Cls 8	Images
Jun 23 2016 2:19PM	Egress	072003	SCANNER	RIGHT	1	0	0	0	0	0	
Jun 23 2016 2:25PM	Egress	072004	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:27PM	Egress	072005	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:37PM	Egress	072006	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:43PM	Egress	072007	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:46PM	Egress	072008	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:49PM	Egress	072009	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:54PM	Egress	072010	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 2:59PM	Egress	072011	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:03PM	Egress	072012	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:03PM	Egress	072013	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:11PM	Egress	072014	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:12PM	Egress	072015	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:13PM	Egress	072016	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:13PM	Egress	072017	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:17PM	Egress	072018	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:18PM	Egress	072019	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:44PM	Egress	072020	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 3:58PM	Egress	072021	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 4:12PM	Egress	072022	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 4:24PM	Egress	072023	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 4:27PM	Egress	072024	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 23 2016 4:28PM	Egress	072025	SCANNER	RIGHT	6	0	0	0	0	0	

Figure 15: SmartPark website data for rest area 23, June 23, 2016

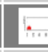
Timestamp	Event Type	Vehicle ID	Sensor Type	Sensor Mount	Class	In Use	Cls 1	Cls 6	Cls 7	Cls 8	Images
Jun 30 2016 12:23AM	Egress	073069	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 12:25AM	Egress	073070	SCANNER	RIGHT	1	0	0	0	0	0	
Jun 30 2016 12:27AM	Egress	073071	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 12:32AM	Egress	073072	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 12:33AM	Egress	073073	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 12:36AM	Egress	073074	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 12:59AM	Egress	073075	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 12:59AM	Egress	073076	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:01AM	Egress	073077	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:18AM	Egress	073078	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:20AM	Egress	073079	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:27AM	Egress	073080	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:33AM	Egress	073081	SCANNER	RIGHT	1	0	0	0	0	0	
Jun 30 2016 1:45AM	Egress	073082	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:46AM	Egress	073083	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:48AM	Egress	073084	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:53AM	Egress	073085	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 1:57AM	Egress	073086	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 2:15AM	Egress	073087	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 2:22AM	Egress	073088	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 2:35AM	Egress	073089	SCANNER	RIGHT	1	0	0	0	0	0	
Jun 30 2016 2:41AM	Egress	073090	SCANNER	RIGHT	6	0	0	0	0	0	
Jun 30 2016 2:43AM	Egress	073091	SCANNER	RIGHT	6	0	0	0	0	0	

Figure 16: SmartPark website data for rest area 23, June 30, 2016

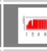
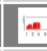
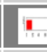
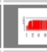
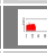
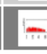
Timestamp	Event Type	Vehicle ID	Sensor Type	Sensor Mount	Class	In Use	Cls 1	Cls 6	Cls 7	Cls 8	Images
Sep 2 2016 7:45AM	Ingress	591753	SCANNER	RIGHT	1	3	2	1	0	0	
Sep 2 2016 7:45AM	Ingress	591754	SCANNER	RIGHT	1	4	3	1	0	0	
Sep 2 2016 7:46AM	Egress	626948	SCANNER	LEFT	6	3	3	0	0	0	
Sep 2 2016 7:47AM	Egress	626949	SCANNER	LEFT	6	2	2	0	0	0	
Sep 2 2016 7:48AM	Egress	626950	SCANNER	LEFT	6	1	1	0	0	0	
Sep 2 2016 7:50AM	Egress	626951	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:50AM	Egress	626952	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:52AM	Egress	626953	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:53AM	Egress	626954	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:54AM	Egress	626955	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:54AM	Egress	626956	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:54AM	Egress	626957	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:55AM	Ingress	591757	SCANNER	RIGHT	1	1	1	0	0	0	
Sep 2 2016 7:58AM	Egress	626958	SCANNER	LEFT	1	0	0	0	0	0	
Sep 2 2016 7:59AM	Ingress	591758	SCANNER	RIGHT	6	1	0	1	0	0	
Sep 2 2016 7:59AM	Egress	626960	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 7:59AM	Ingress	591759	SCANNER	RIGHT	1	2	1	1	0	0	
Sep 2 2016 8:06AM	Egress	626962	SCANNER	LEFT	6	1	1	0	0	0	
Sep 2 2016 8:07AM	Egress	626963	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 8:08AM	Ingress	591760	SCANNER	RIGHT	1	1	1	0	0	0	
Sep 2 2016 8:11AM	Egress	626964	SCANNER	LEFT	6	0	0	0	0	0	
Sep 2 2016 8:12AM	Ingress	591763	SCANNER	RIGHT	1	1	1	0	0	0	
Sep 2 2016 8:20AM	Egress	626966	SCANNER	LEFT	6	0	0	0	0	0	

Figure 17: SmartPark website data for rest area 45, September 2, 2016

Appendix C: User Survey Responses
C1: Respondent Information

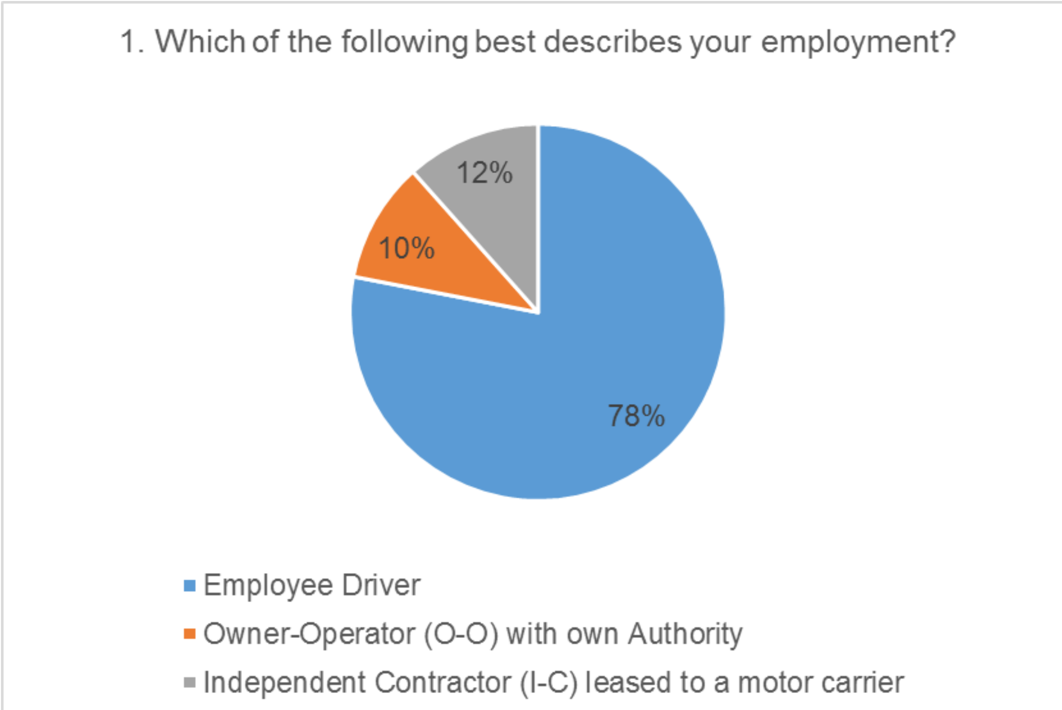


Figure 18: Responses to user's survey, question 1

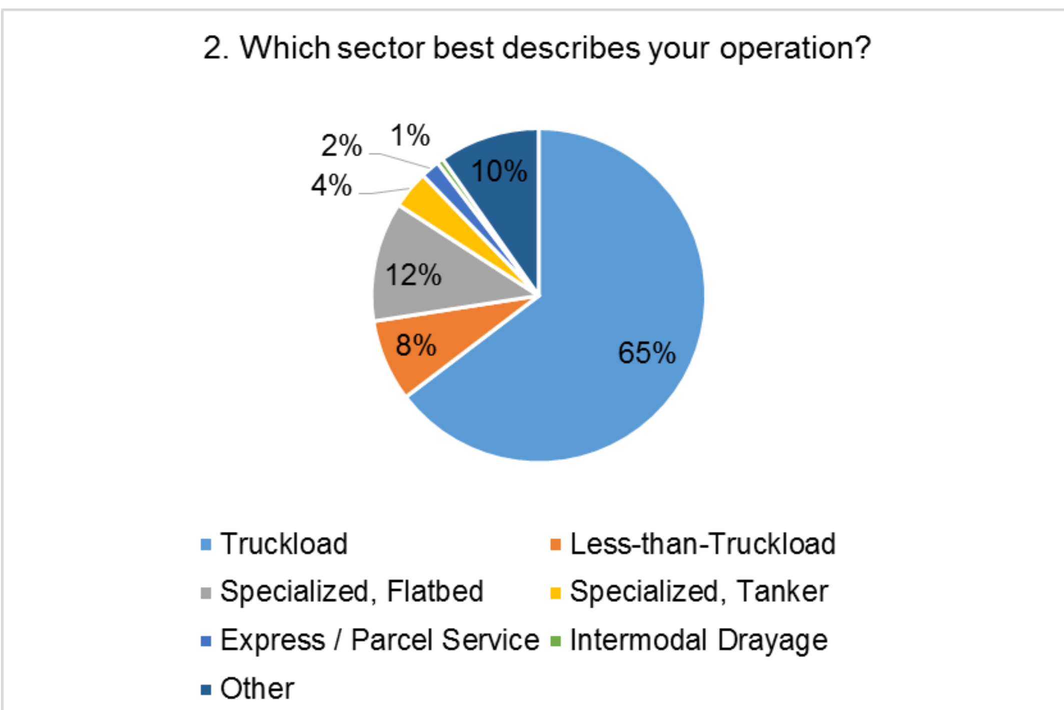


Figure 19: Responses to user's survey, question 2

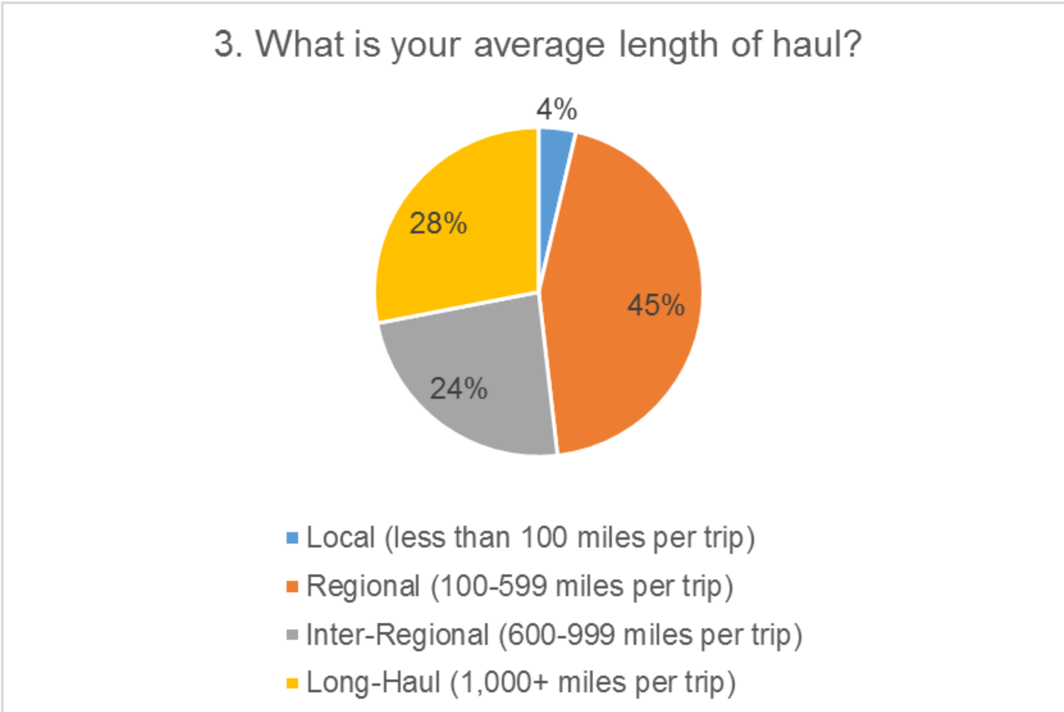


Figure 20: Responses to user's survey, question 3

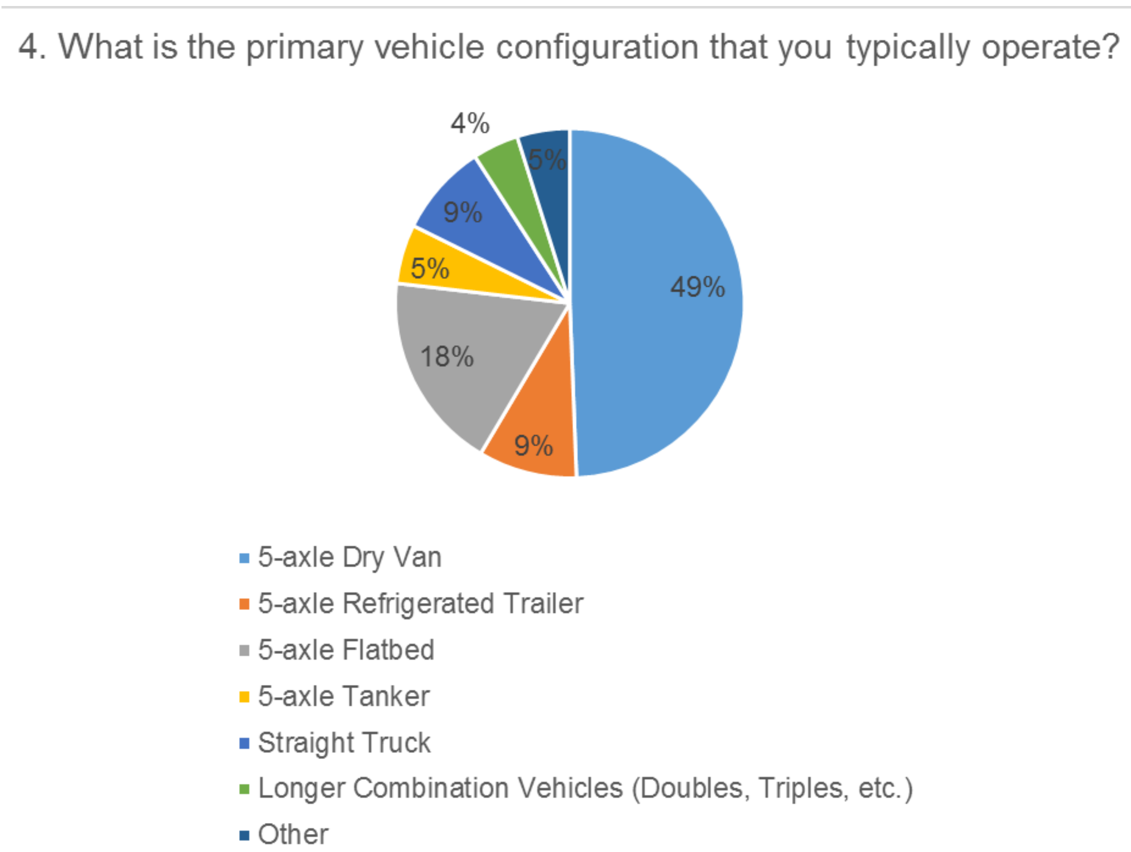


Figure 21: Responses to user's survey, question 4

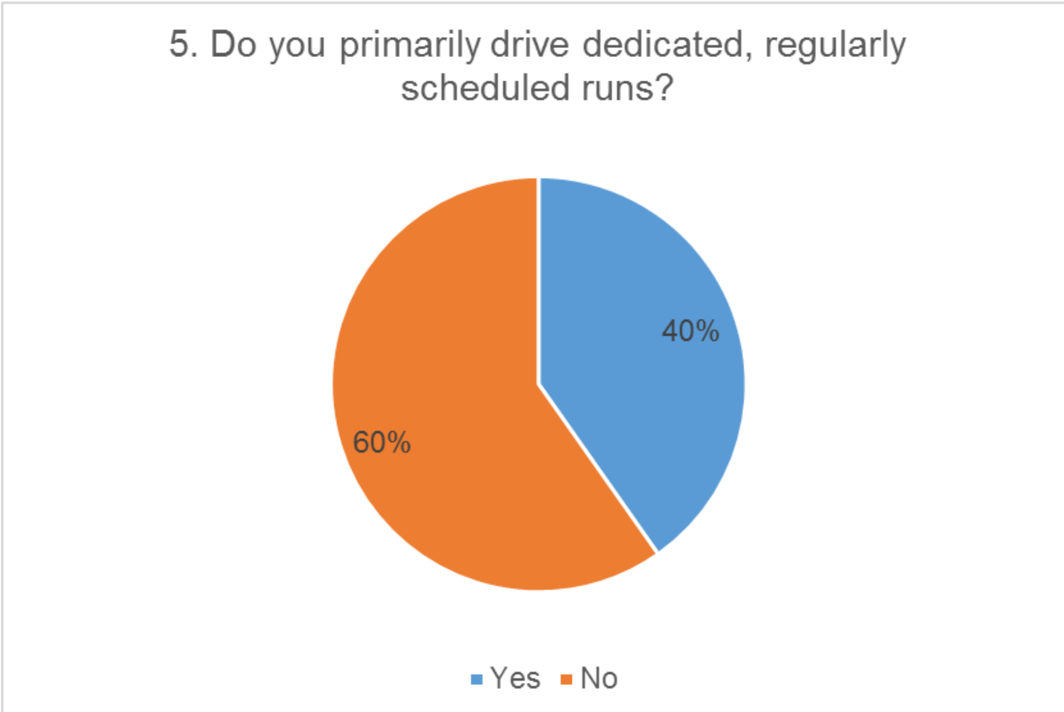


Figure 22: Responses to user's survey, question 5

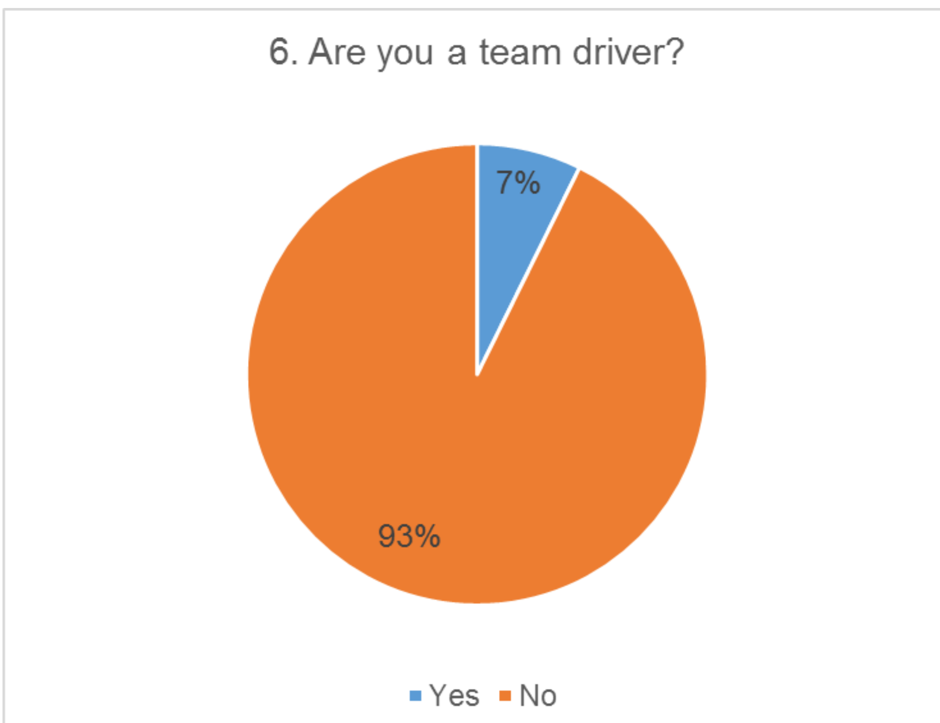


Figure 23: Responses to user's survey, question 6

C2: Respondent's Rest Area Usage Habits

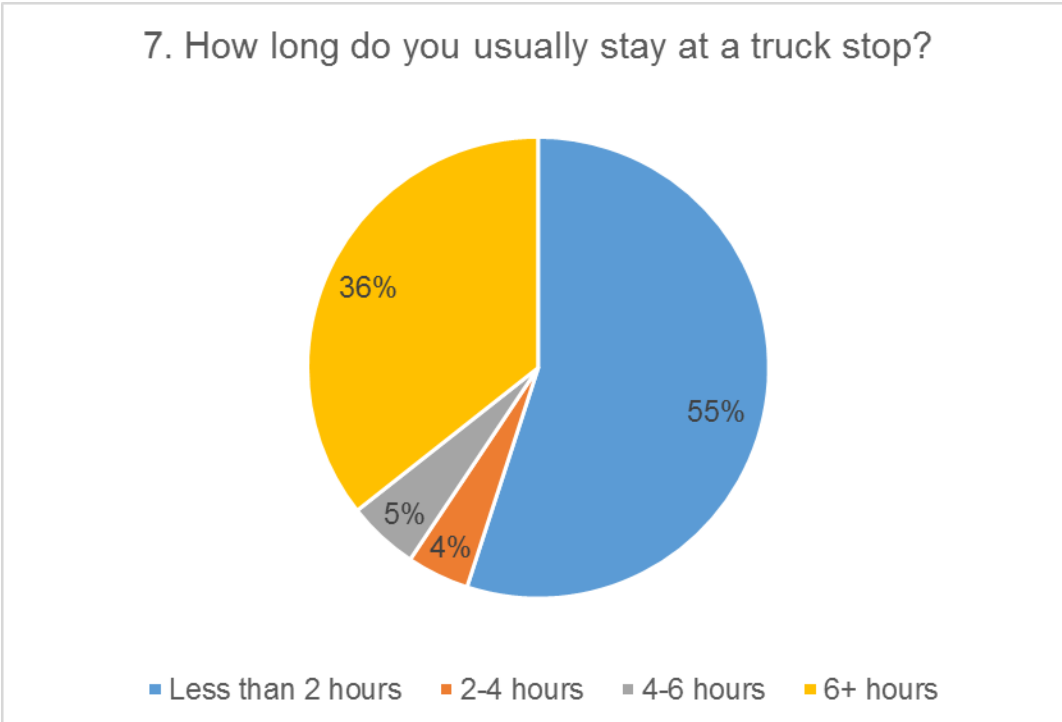


Figure 24: Responses to user's survey, question 7

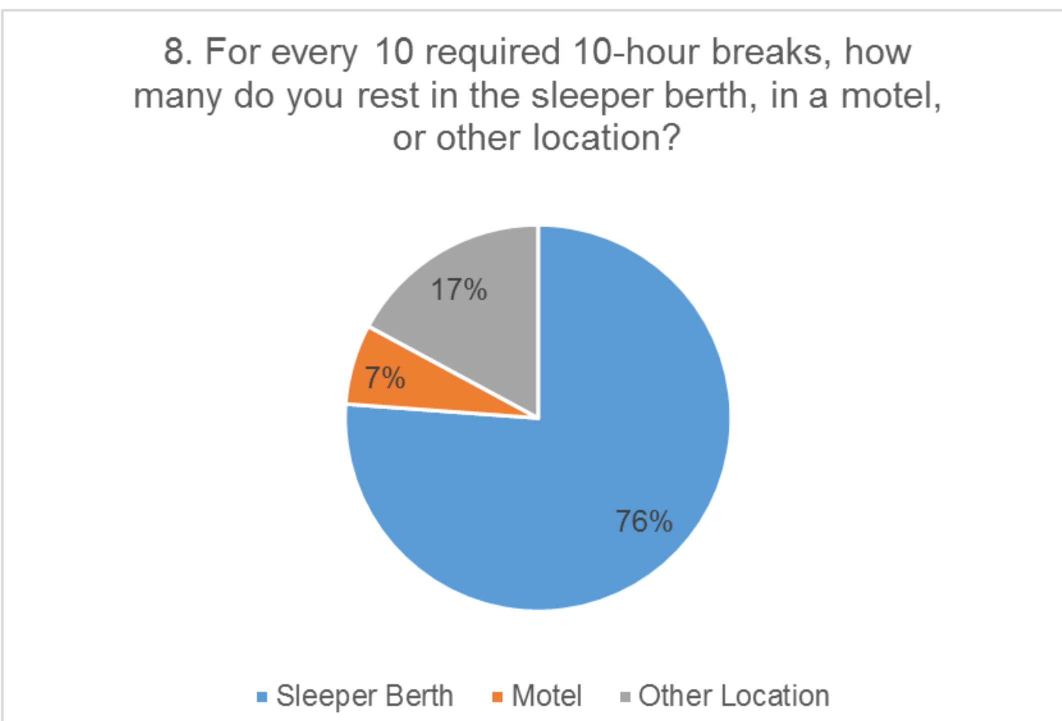


Figure 25: Responses to user's survey, question 8

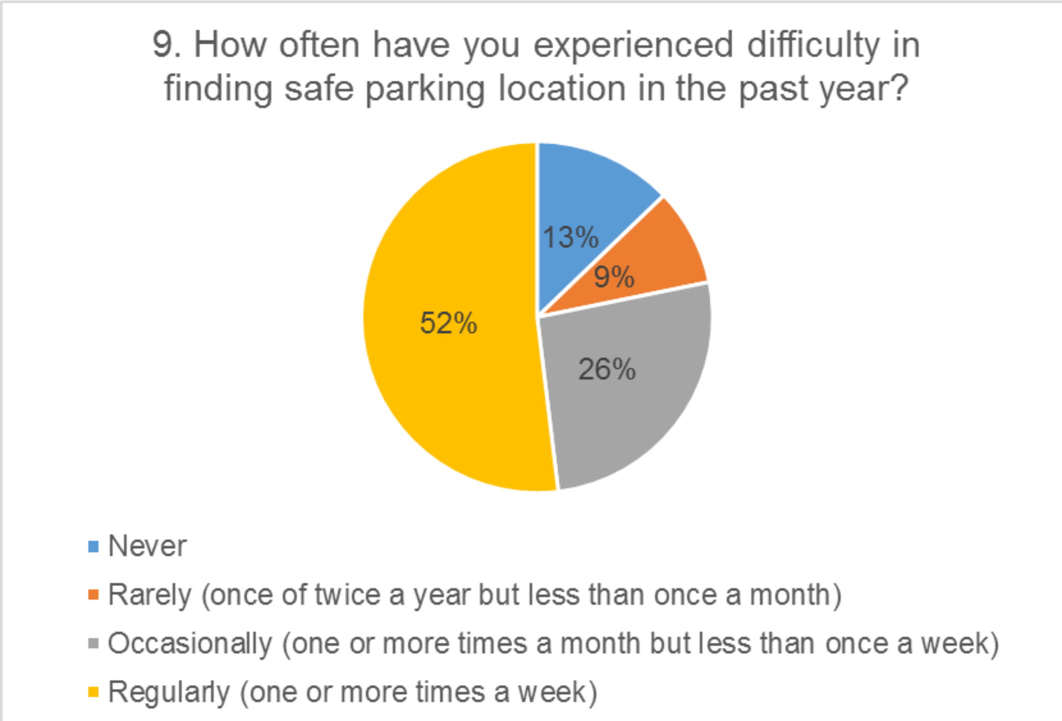


Figure 26: Responses to user's survey, question 9

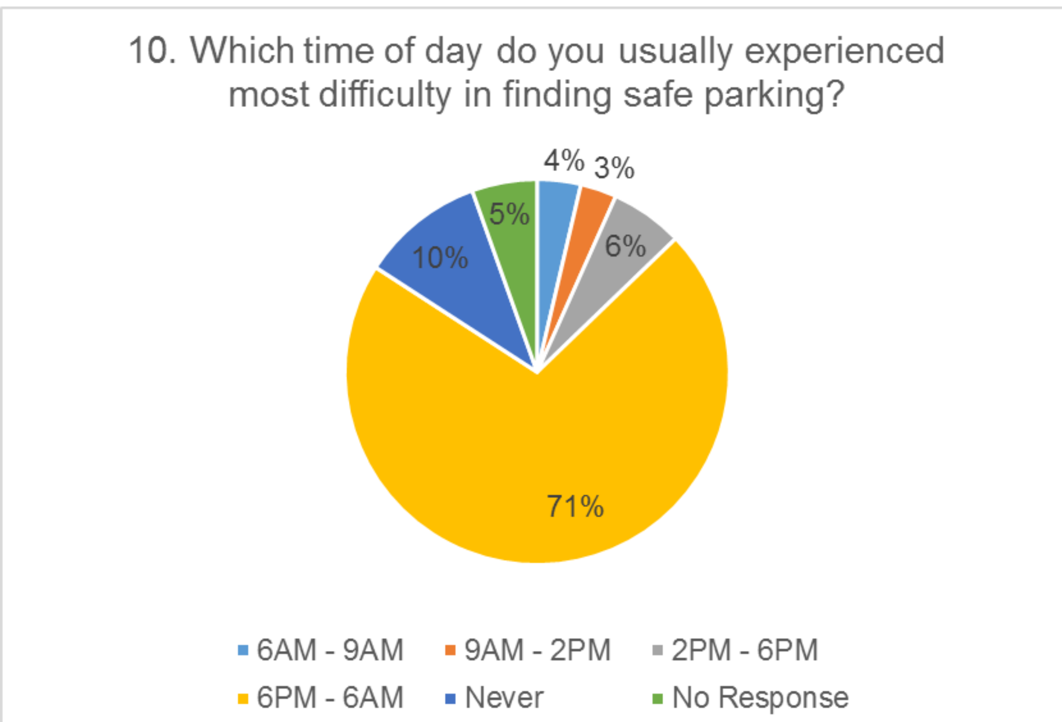


Figure 27: Responses to user's survey, question 10

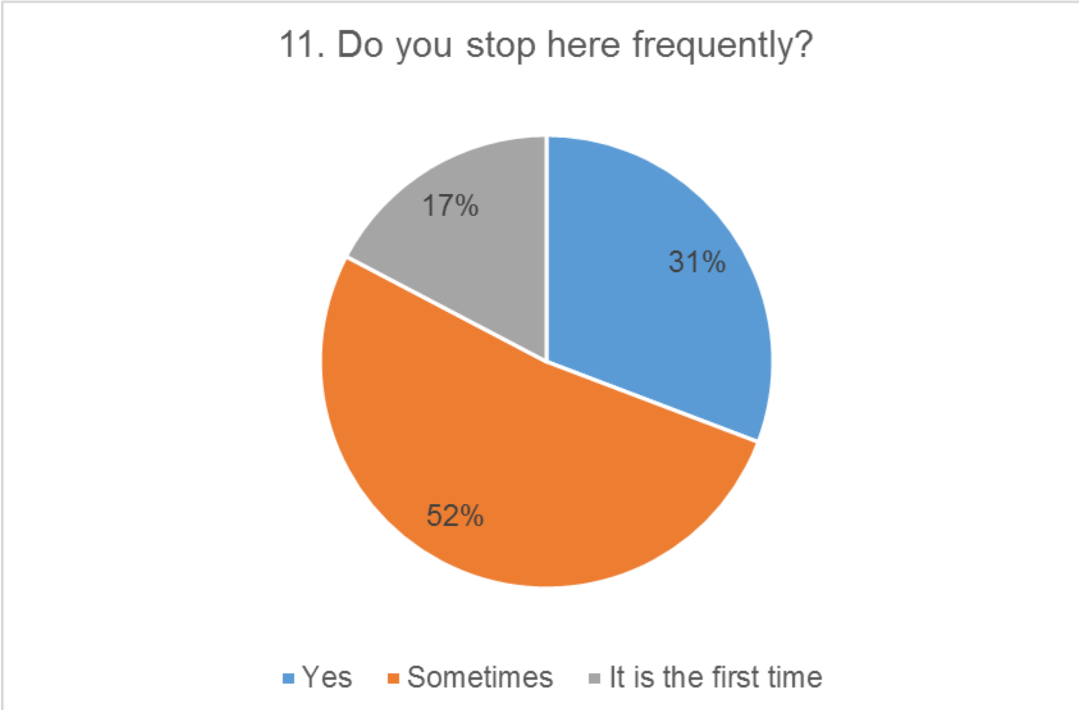


Figure 28: Responses to user's survey, question 11

C3: Respondent Knowledge of SmartPark

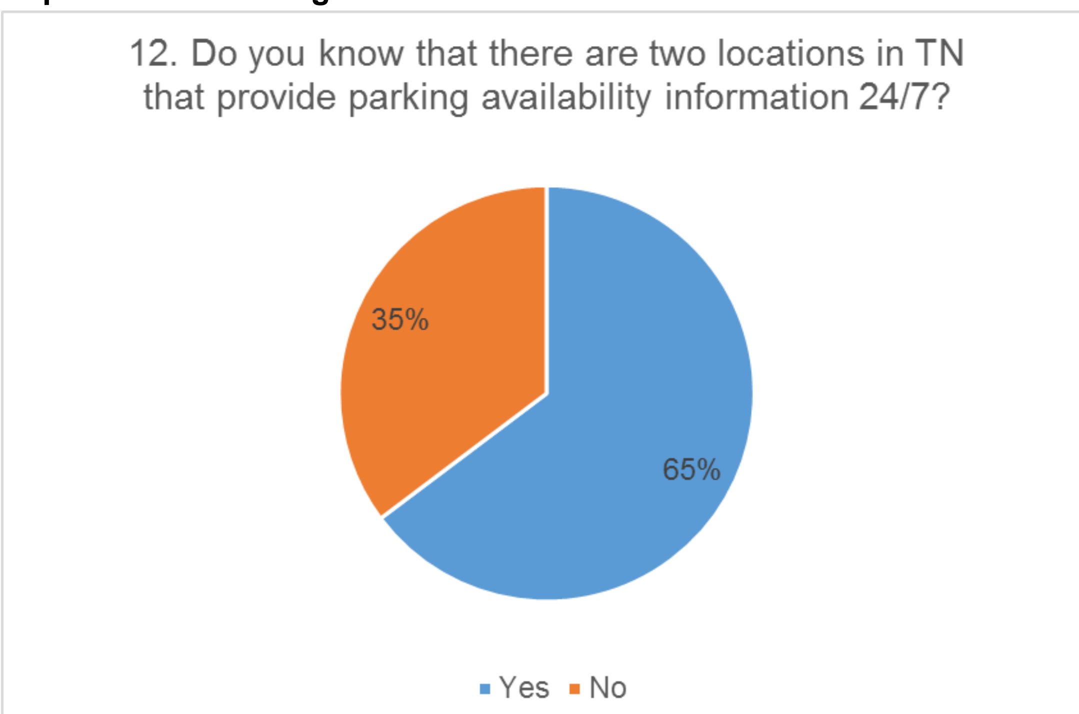


Figure 29: Responses to user's survey, question 12

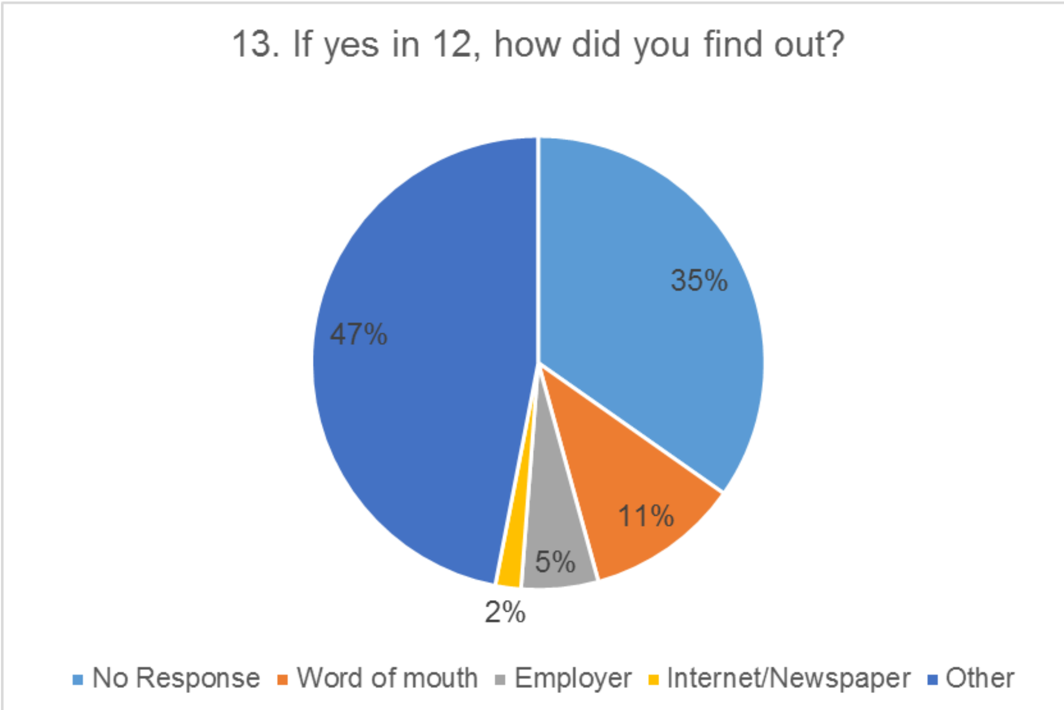


Figure 30: Responses to user's survey, question 13

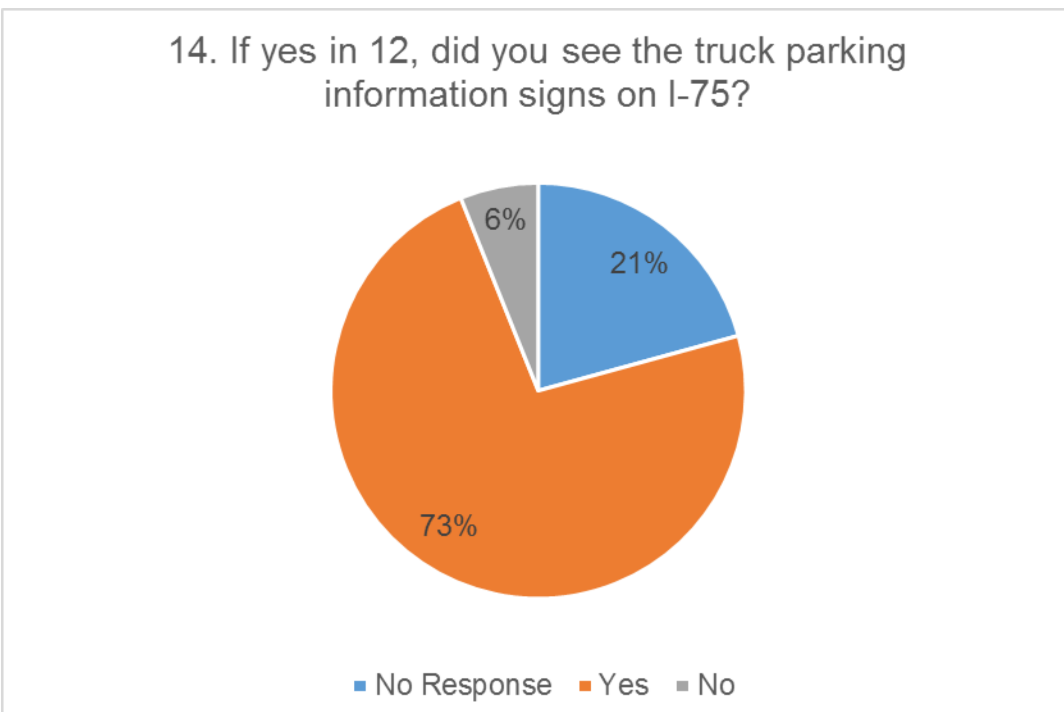


Figure 31: Responses to user's survey, question 14

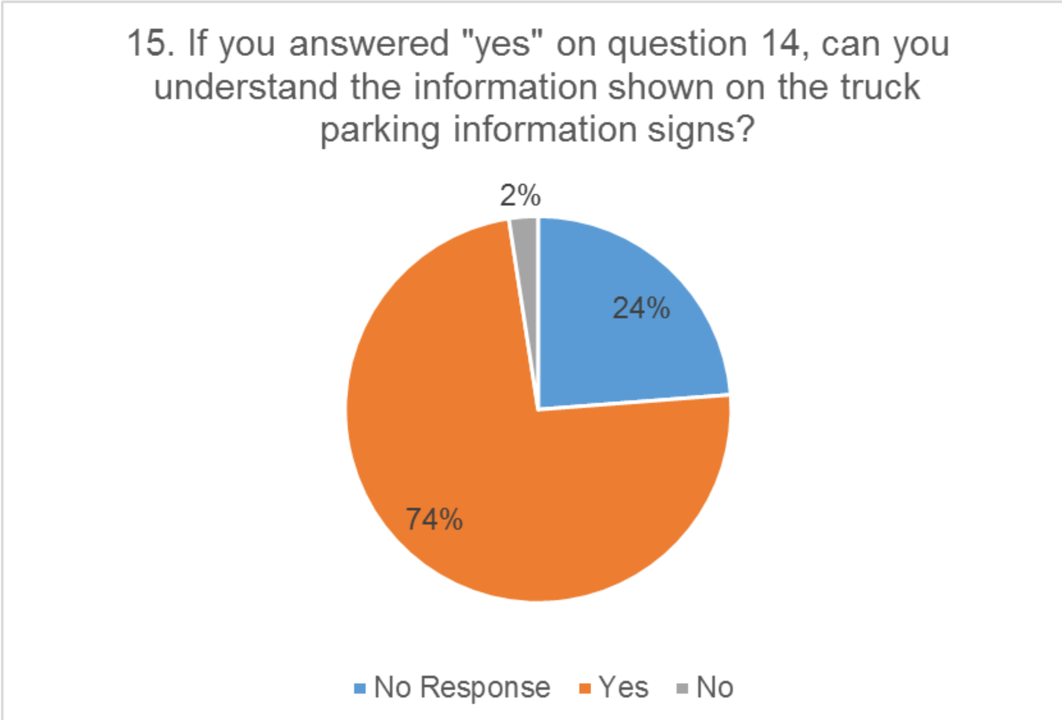


Figure 32: Responses to user's survey, question 15

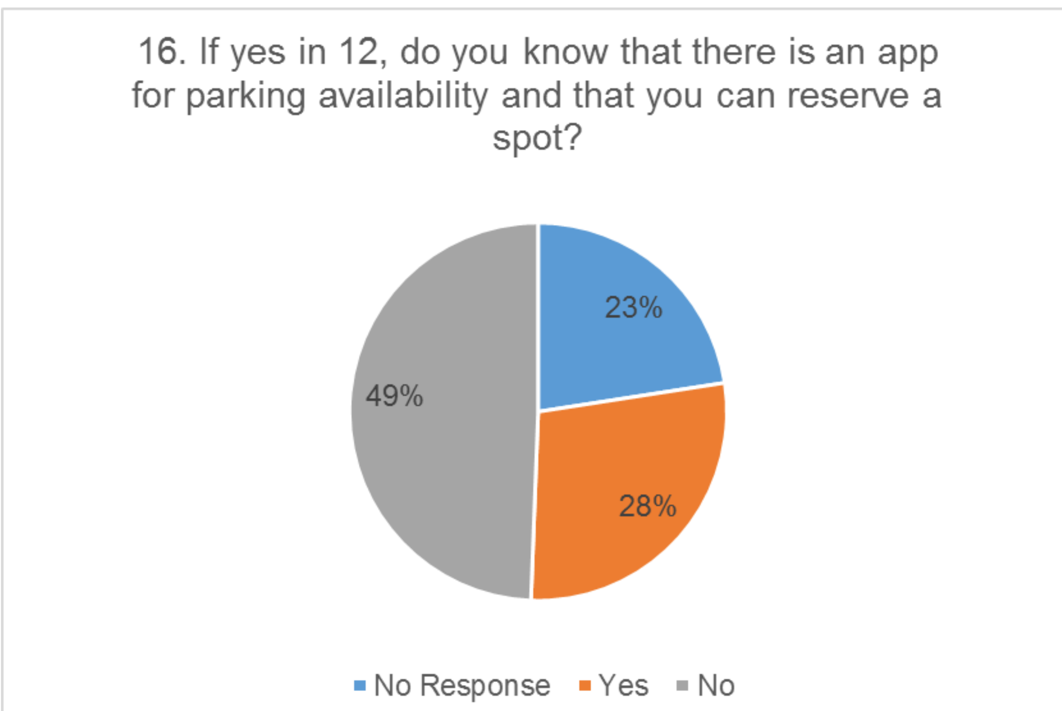


Figure 33: Responses to user's survey, question 16

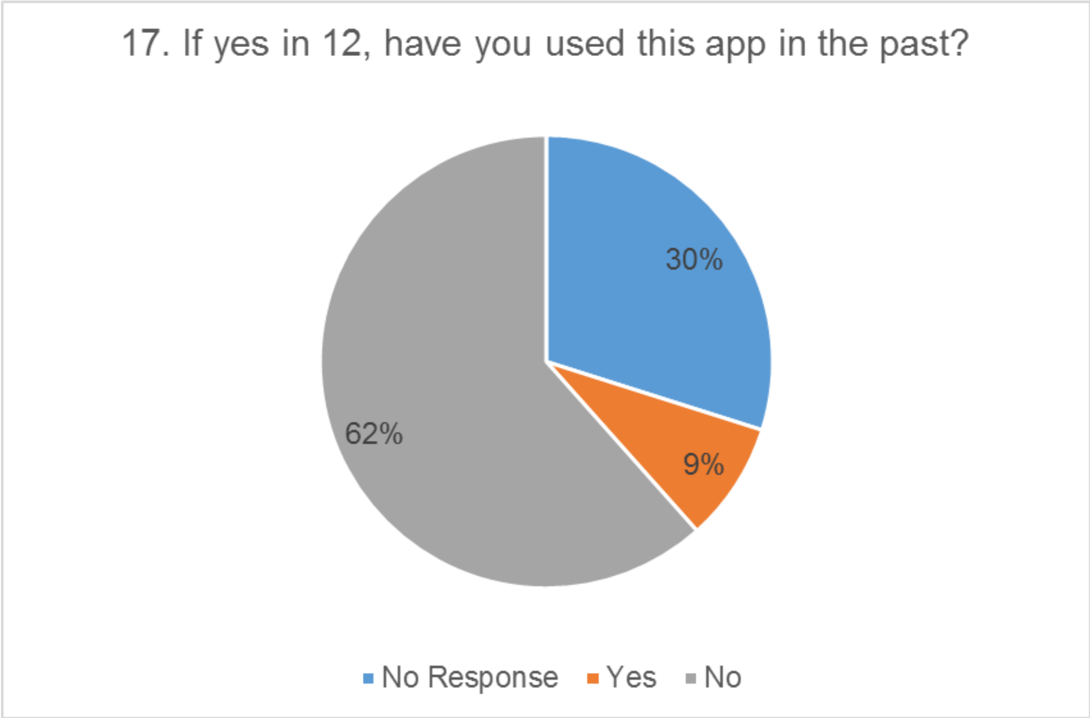


Figure 34: Responses to user's survey, question 17

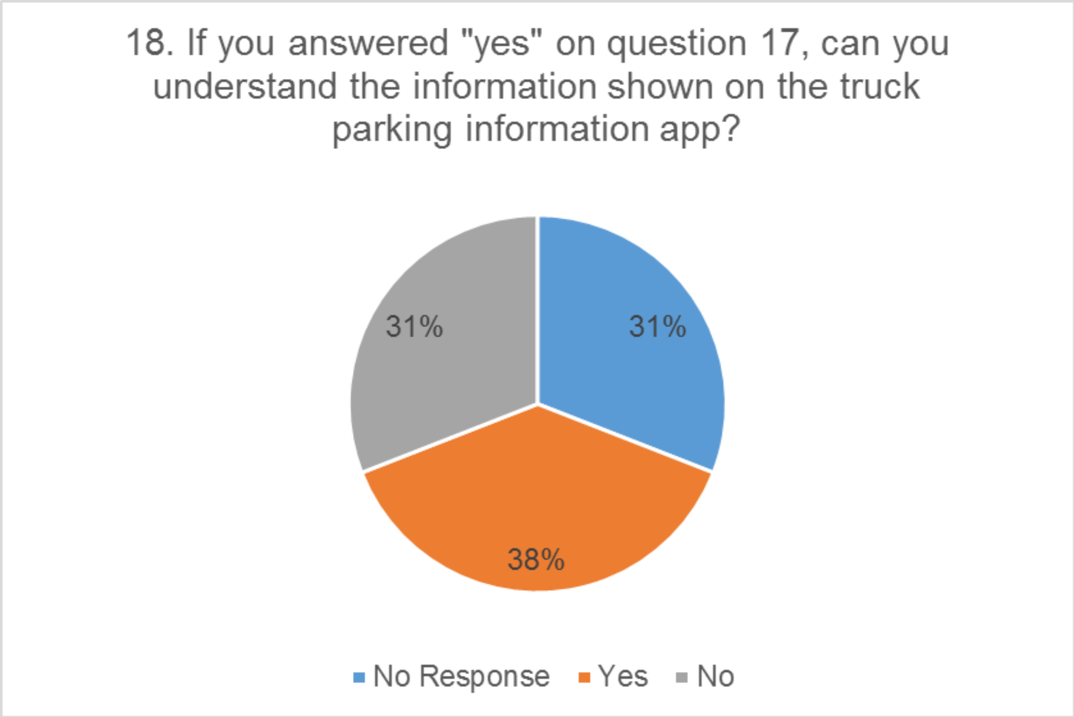


Figure 35: Responses to user's survey, question 18

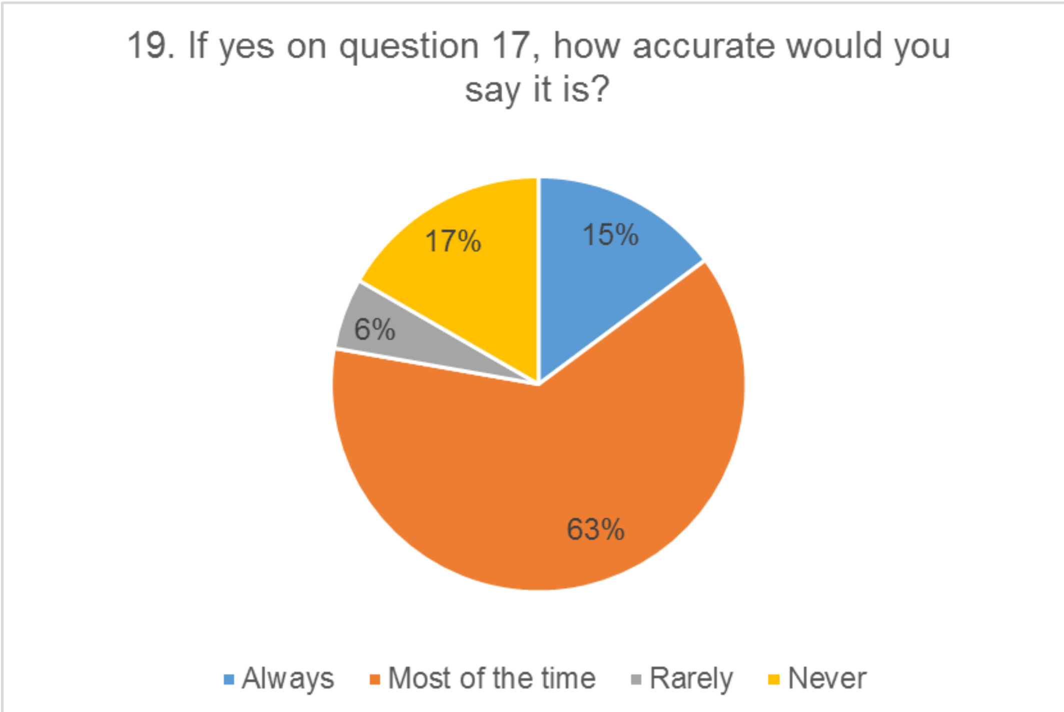


Figure 36: Responses to user's survey, question 19

C4: Willingness to Pay

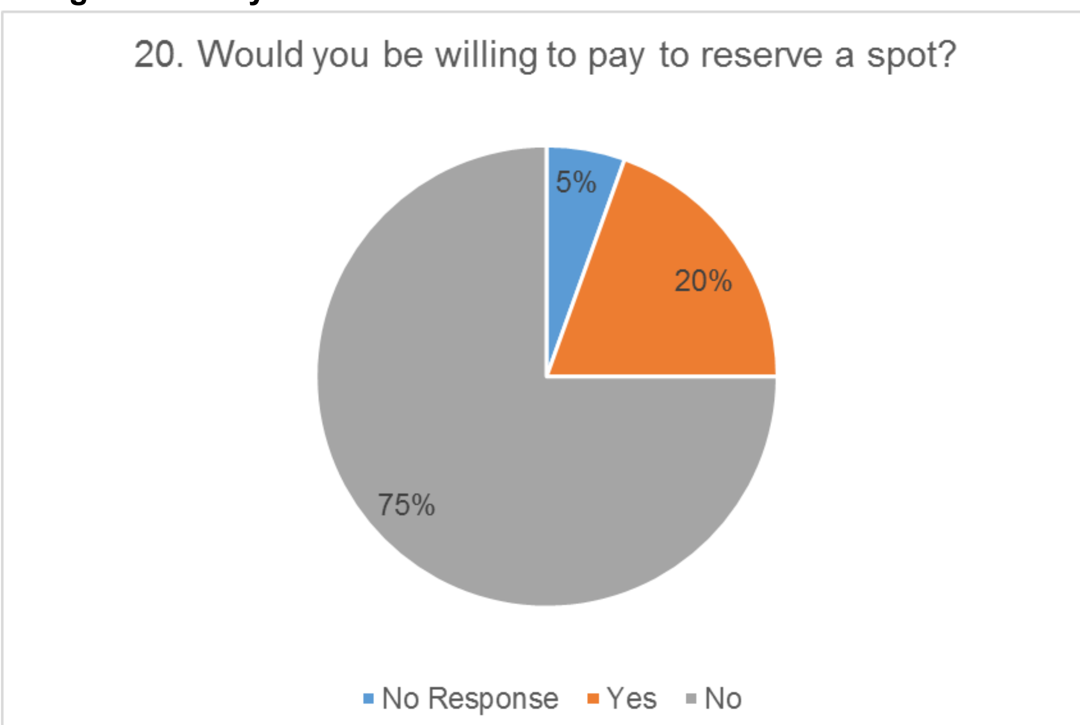


Figure 37: Responses to user's survey, question 20

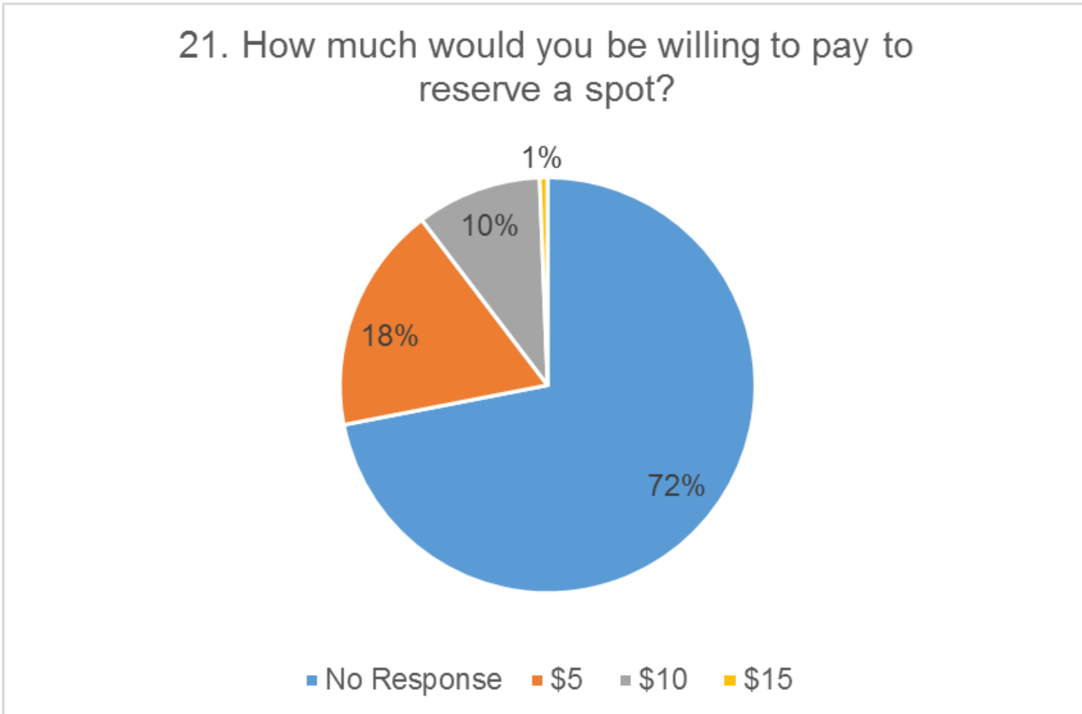


Figure 38: Responses to user's survey, question 21

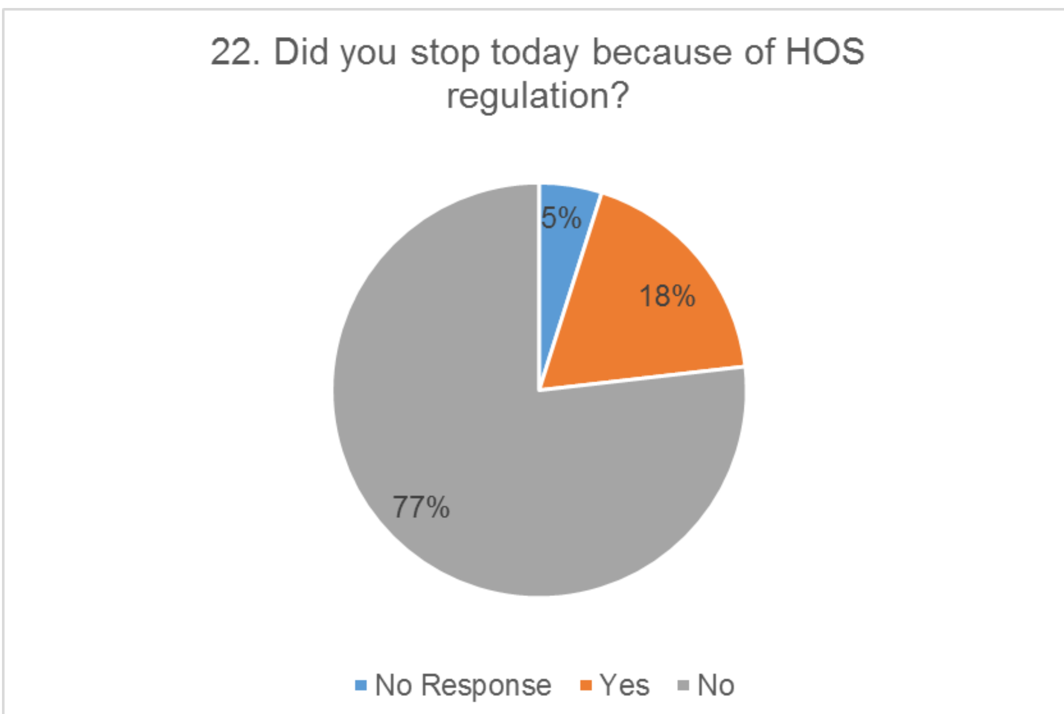


Figure 39: Responses to user's survey, question 22

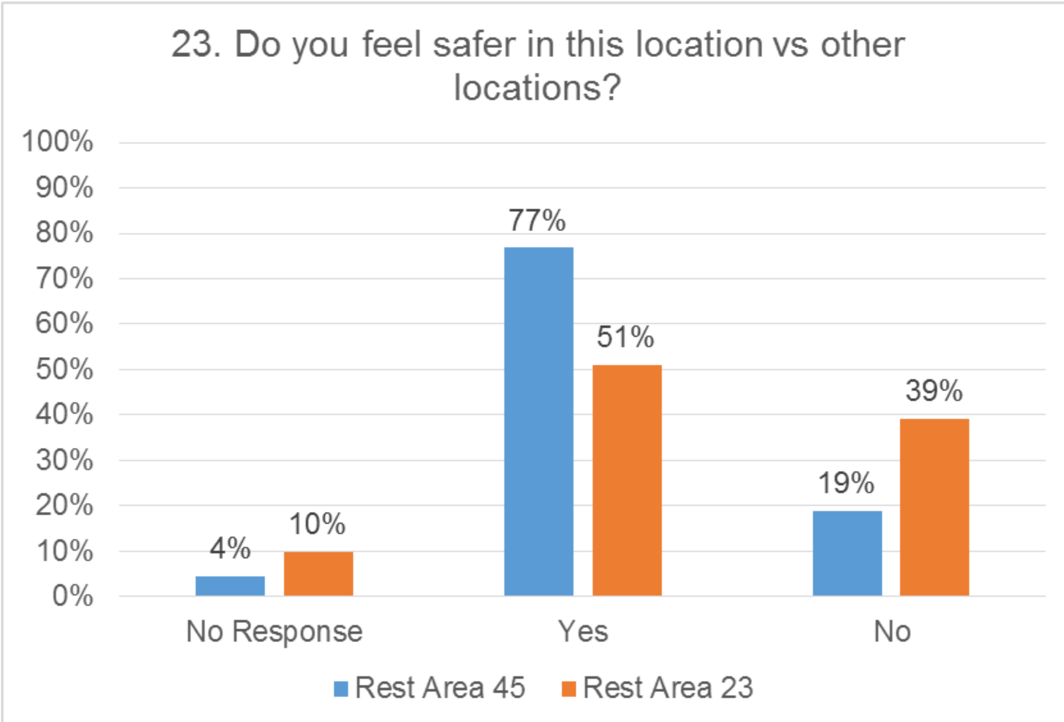


Figure 40: Responses to user's survey, question 23

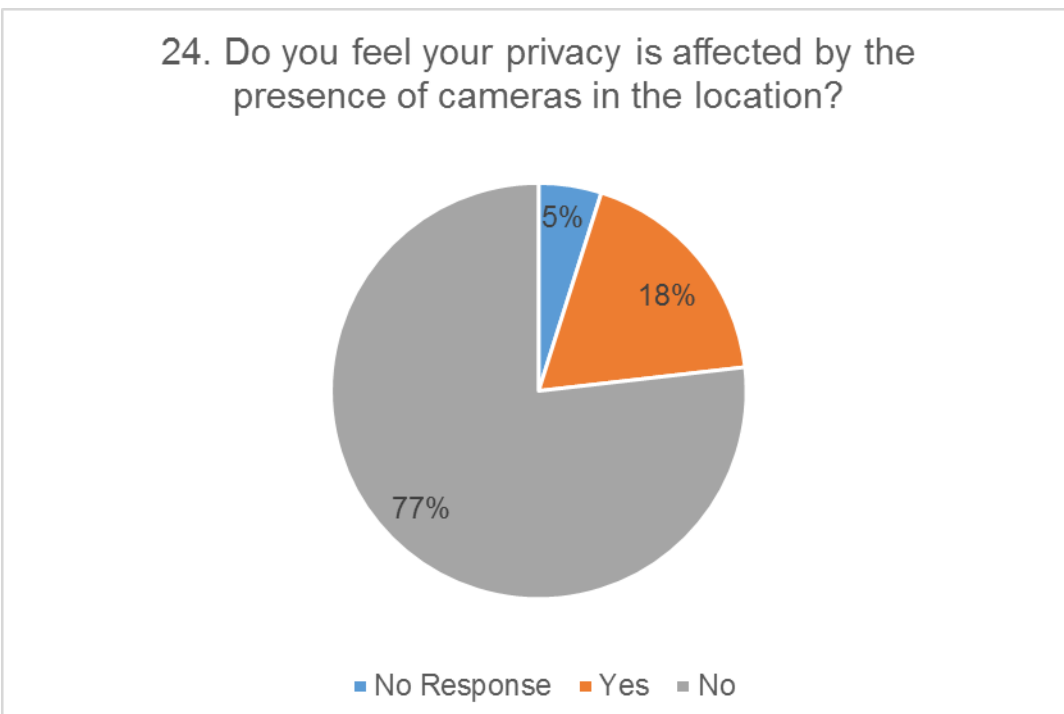


Figure 41: Responses to user's survey, question 24

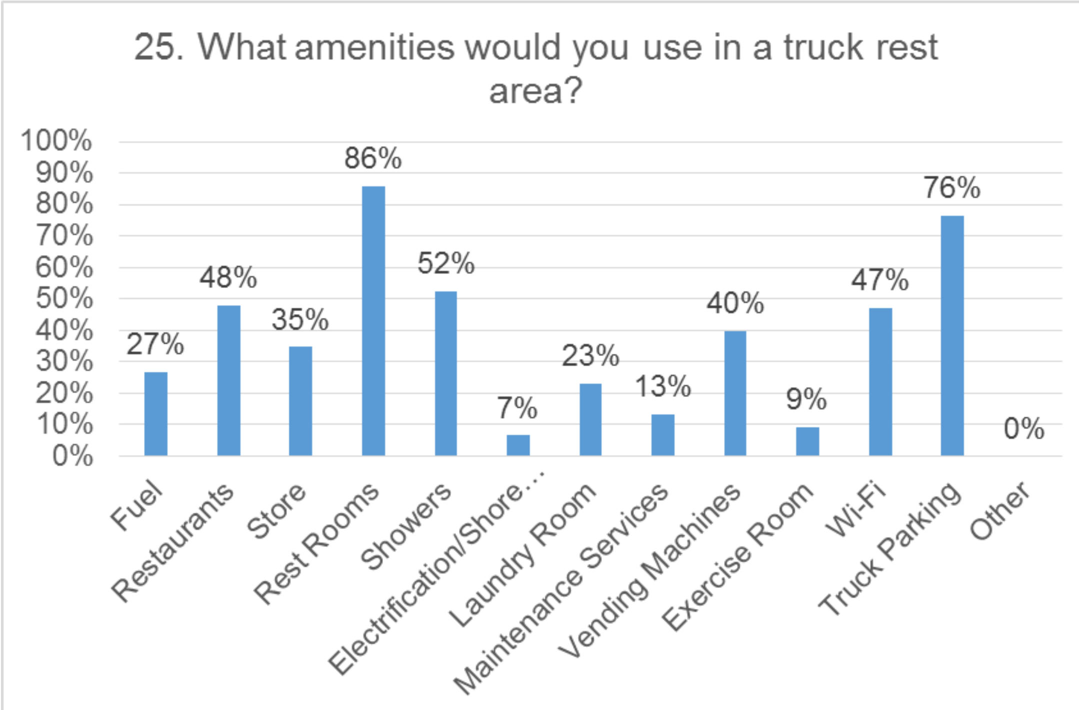


Figure 42: Responses to user's survey, question 25

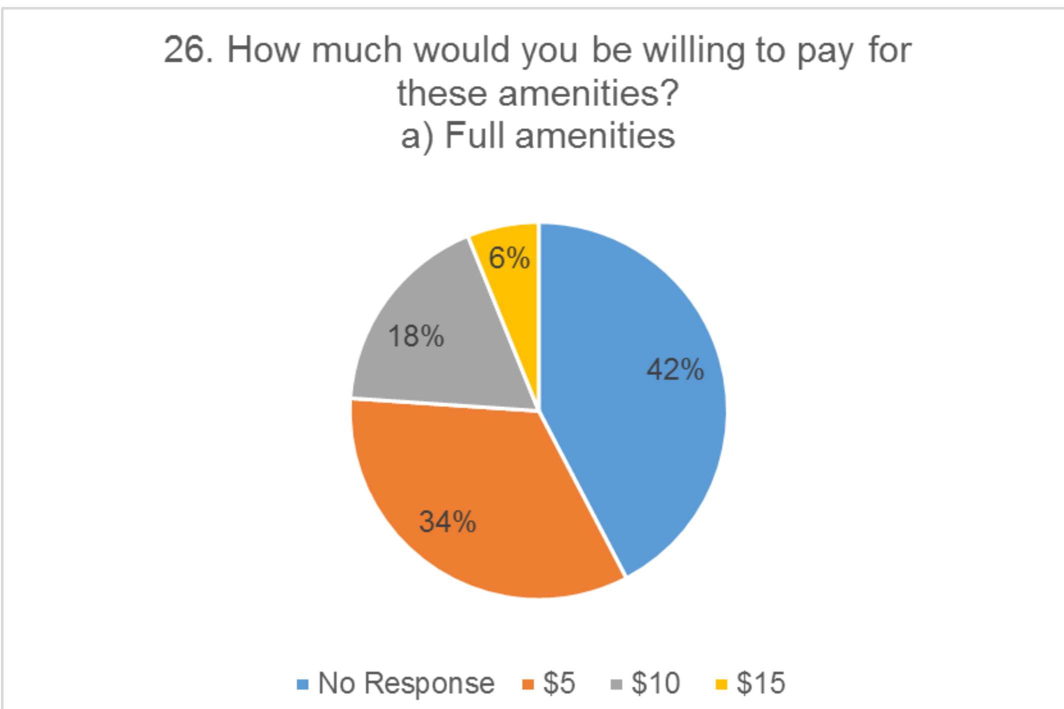


Figure 43: Responses to user's survey, question 26a

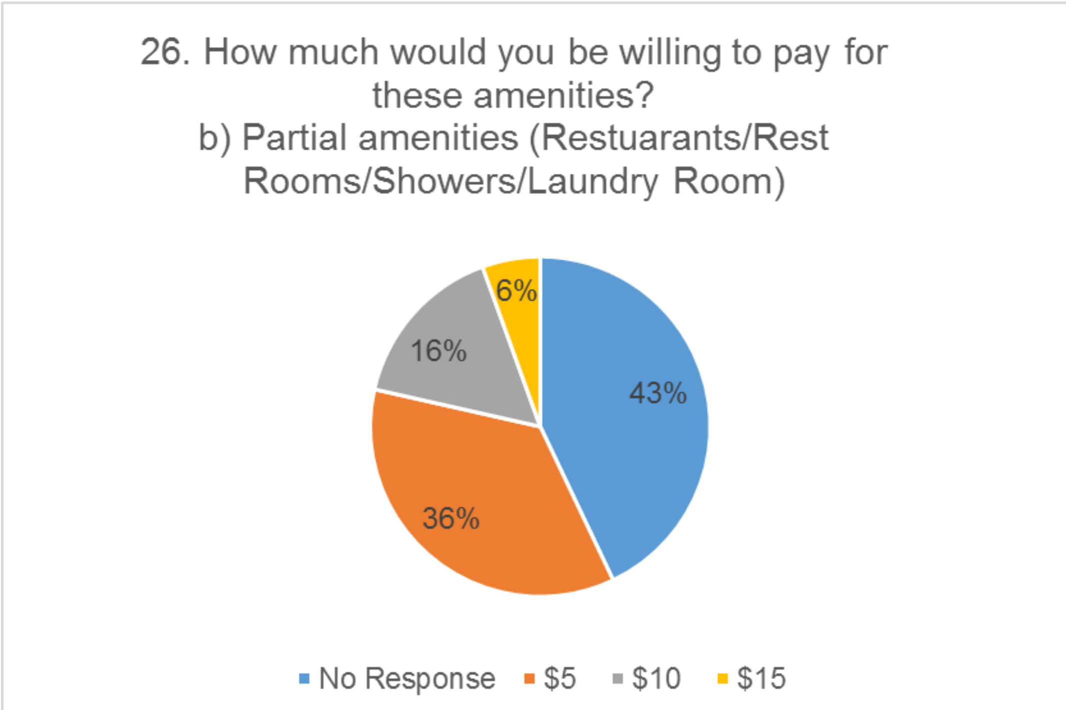


Figure 44: Responses to user's survey, question 26b

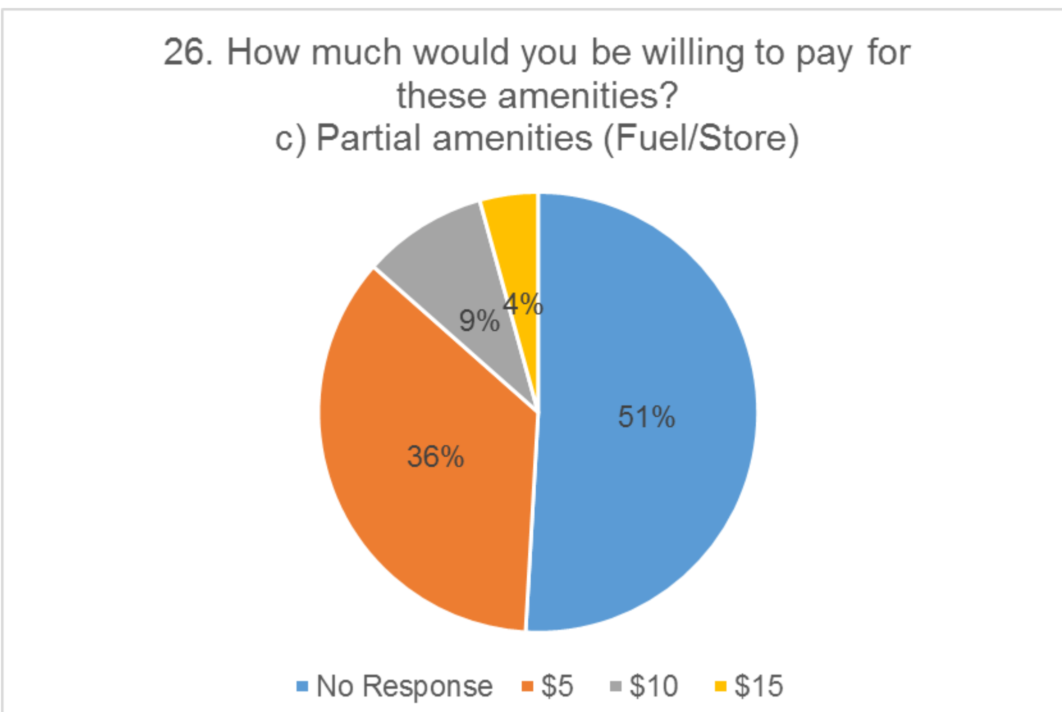


Figure 45: Responses to user's survey, question 26c