UNDERSTANDING TRUCK PARKING BEHAVIOR AND CHOICE OF COMMERCIAL MOTOR VEHICLE OPERATORS: IMPACTS ON ROADWAY SAFETY

FINAL PROJECT REPORT

by

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Sponsorship
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Pacific Northwest Transportation Consortium (PacTrans)
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In cooperation with US Department of Transportation-Research and Innovative Technology Administration (RITA)

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
Understanding Truck Parking Behavior and Choice of Commercial Motor Vehicle Operators: Impacts on Roadway Safety	May 2018
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Salvador Hernandez and Nabeel Saleem Saad Al-Bdairi– Oregon State University	
9. Performing Organization Name and Address	**10. Work Unit No. (TRAIS)**
PacTrans Pacific Northwest Transportation Consortium University Transportation Center for Region 10 University of Washington More Hall 112 Seattle, WA 98195-2700	**11. Contract or Grant No.** DTRT-13-G-UTC40
12. Sponsoring Organization Name and Address	**13. Type of Report and Period Covered**
United States of America Department of Transportation Research and Innovative Technology Administration	Research **14. Sponsoring Agency Code**

15. Supplementary Notes

Report uploaded at www.pacTrans.org

16. Abstract

It is nationally recognized that commercial motor vehicle (CMV) operators often cannot find adequate and safe parking for rest purposes. This is especially true for the Pacific Northwest, where high-use corridor rest areas are experiencing demand for truck parking that exceeds capacity. These rest areas are intended for short-term safety breaks, yet they are increasingly used for long-term parking. With this in mind, the present study sought to identify the factors that influence CMV operator truck parking behavior and choices through the application of discrete choice modeling approaches. This was achieved through the use of a truck driver survey regarding their experiences related to the availability of safe and adequate parking. The survey was geographically focused on drivers and freight activity throughout the Pacific Northwest in order to make better inferences about truck parking along the study corridor. The data and information collected were then utilized to estimate a binary outcome (logit) model to evaluate how different factors, obtained from the driver survey, affect drivers' likelihood of finding safe and adequate parking, from their perspective. Results showed that drivers of less-than-truckload (LTL) shipments and weekend shipments, and older drivers perceived having significantly fewer challenges finding safe and adequate parking. Findings from the current study can be used to better prioritize efforts across the country in regard to safe and adequate truck parking. The findings of this study can also provide information that can aid safety planners and the trucking industry in identifying appropriate measures to help mitigate the number and severity of crashes due to unsafe truck parking practices by CMV operators.

17. Key Words	18. Distribution Statement	
	No restrictions.	
19. Security Classification (of this report)	**20. Security Classification (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified.	Unclassified.		NA

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

Table of Contents

List of Figures

List of Tables

List of Abbreviations (optional)

PacTrans: Pacific Northwest Transportation Consortium

CMV: Commercial motor vehicle

HOS: Hours of service

LTL: Less-than-truckload

ATRI: American Transportation Research Institute

FHWA: Federal Highway Administration

Acknowledgments

The authors want to acknowledge the Oregon Department of Transportation (ODOT) for its support and guidance regarding large truck parking issues in the Pacific Northwest. The authors also want to thank ODOT for its cooperation during the current study and for providing the survey results used for this analysis. In addition, the authors want to acknowledge the Pacific Northwest Transportation Consortium (PACTRANS) for its funding and student support as part of the small-sized, multi-institutional funding program.

Executive Summary

Limited availability of adequate parking is an ongoing issue for large truck drivers throughout the United States. A 2012 study by the Federal Highway Administration (FHWA) reported that national truck parking shortages are severe and widespread, and 75 percent of the surveyed drivers reported having problems finding secure parking during the night. The results of such shortages and the issues associated with finding adequate parking are safety impacts to all highway users resulting from large trucks parking in unsafe locations (often due to drivers pushing their hours-of-service limits to find safe and adequate parking). The nationally recognized inability of commercial motor vehicle (CMV) operators to find adequate and safe parking for rest purposes is especially true for the Pacific Northwest, where high-use corridor rest areas are experiencing demand for truck parking that exceeds capacity. These rest areas are intended for short-term safety breaks, yet they are increasingly used for long-term parking. Private truck stops are also experiencing capacity shortfalls. The recent economic recovery and driver hours-of-service (HOS) regulations have contributed to rising demand. In addition, winter weather conditions add to the demand for already stressed truck parking facilities.

Because of truck parking shortages and limits on stays in public rest areas, CMV operators may contribute to unsafe situations by driving without a needed short break and/or by parking on roadway access ramps, shoulders, at highway interchanges, and on facilities running through cities and towns. Many states, including in the Pacific Northwest (e.g., Oregon and Washington), prohibit parking on a throughway, yet enforcement of illegal truck parking has been a low priority for state police and other law enforcement officers. This problem is expected to increase, as freight movement by truck is forecast to increase about 70 percent (tonnage) by 2035 in parts of the Northwest.

With these issues in mind, the present study sought to identify the factors that influence CMV operator truck parking behavior and choices through the application of discrete choice modeling approaches. This was achieved through the use of a truck driver survey regarding their experiences related to the availability of safe and adequate parking. The survey was geographically focused on drivers and freight activity throughout the Pacific Northwest to better infer truck parking along the study corridor. The data and information collected were then utilized to estimate a binary outcome (logit) model to evaluate how different factors, obtained from the driver survey, affect drivers' perceptions of the likelihood of finding safe and adequate parking. Results showed that drivers of less-than-truckload (LTL) shipments, weekend shipments, and older drivers reported significantly fewer challenges finding safe and adequate parking.

The findings from the current study can be used to better prioritize efforts across the country regarding safe and adequate truck parking. The findings of this study can also provide information that can aid safety planners and the trucking industry in identifying appropriate measures to help mitigate the number and severity of crashes due to unsafe truck parking practices by CMV operators.

1.0 Introduction

It is nationally recognized that commercial motor vehicle (CMV) operators often cannot find adequate and safe parking for rest purposes. This is especially true in the Pacific Northwest, where high-use corridor rest areas are experiencing demand for truck parking that exceeds capacity (FHWA, 2015). These rest areas are intended for short-term safety breaks, yet they are increasingly used for long-term parking. Private truck stops are also experiencing capacity shortfalls. The recent economic recovery and driver hours-of-service regulations have contributed to the rising demand. In addition, winter weather conditions add to the demand for already stressed truck parking facilities. Recent studies by Islam and Hernandez (2013) and Pahukula et al. (2015) showed that factors related to weather and fatigue increase the likelihood and severity of CMV involved crashes.

Because of truck parking shortages and limits on stays in public rest areas, CMV operators may contribute to unsafe situations by driving without a needed short break and/or by parking on roadway access ramps, shoulders, at highway interchanges, and on facilities running through cities and towns. Many states, including in the Pacific Northwest (e.g., Oregon and Washington), prohibit parking on a throughway, yet enforcement of illegal truck parking has been a low priority for state police and other law enforcement officers. This problem is expected to increase, as freight movement by truck is forecast to increase about 70 percent (tonnage) by 2035 in parts of the Northwest (Oregon Freight Plan, 2011).

With these issues in mind, the present study sought to identify the factors that influence CMV operator truck parking behavior and choices through the application and performance-based comparison of two "heterogeneity" models, namely the random parameters and latent class discrete choice modeling approaches (Hensher et al., 2015; Mannering et al., 2016). This was

done by using a recent stated preference survey administered by the authors regarding how and why drivers choose their parking locations in the Northwest, the use of the Oregon Statewide Crash Data System, an extensive database collected and maintained by the Oregon Department of Transportation (ODOT), and data provided by the Washington State Department of Transportation (WSDOT). The findings of this study can provide information that can aid safety planners and the trucking industry in identifying appropriate measures to help mitigate the number and severity of crashes due to unsafe truck parking practices by CMV operators.

Over the last two decades a number of studies have specifically focused on passenger car parking behavior and choice (Benenson et al., 2008; Bonsall and Palmer, 2004; Caicedo et al., 2006; Thompson and Richardson, 1998; Young et al., 1991). However, little consideration has been given to CMV parking behavior and choice. This is significant, as CMV parking searches have a substantial impact on transportation road networks. This is the case for the following reasons: first, CMVs make up to 20 percent of all vehicles on most freight travel road networks, and second, CMVs park more often than passenger cars, creating potential safety hazards because of the hour-of-services regulations that CMV operators must follow (Muñuzuri et al., 2002). By neglecting to consider CMVs, researchers have neglected a significant safety hazard to general road users. Moreover, CMV parking behavior is very different from that of passenger cars, given that CMV operators are motivated to make deliveries on time and are constrained by pick-up and delivery times (Trombly, 2003). Consequently, CMV operators spend less time finding adequate and safe parking and are therefore much more inclined to park illegally.

Regarding CMV parking behavior and choice, the literature is sparse. The existing studies primarily focused on understanding the factors contributing to CMV parking choice outside the U.S. by utilizing standard multinomial logit (MNL) modeling frameworks with stated

preference and revealed preference survey data with no linkages to existing crash data (Axhausen and Polak, 1991; Nourinejad et al., 2014; Teknomo and Hokao, 1997; Van Der Goot, 1982). Furthermore, the MNL model used in those previous studies had three primary limitations that, if not addressed, could lead to inconsistent (i.e., incorrect) estimates of the effects of variables on CMV operator parking behavior and choice; these were random taste variations, unrestricted substitution, and correlation in unobserved factors (referred to as unobserved heterogeneity) (Hensher et al., 2015; Mannering et al., 2016). Recent studies have addressed these issues through the application of "heterogeneity" methods that account for unobserved heterogeneity in addition to the other limitations; for example, data not captured in the data set such as weather conditions at the time of the parking choice, which continually change over time, as well as the truck driver's response to the changing weather conditions. Hence, the heterogeneity-based models allow the analyst to account for these variations and make more informed inferences regarding the effects of contributing factors. For a complete review on the heterogeneity methods, the reader is directed to Mannering et al. (2016).

In summary, this research aimed to address the issues related to the CMV parking behaviors and choices of U.S.-based CMV operators, lack of linkages between survey data and existing crash data, and modeling of the limitations from previous work through the development and comparison of heterogeneity-based methods. The results of this study can be immediately used by safety planners and the trucking industry.

2.0 Literature Review

The limited availability of adequate parking is an ongoing issue for large truck drivers throughout the United States. A 2012 study by the Federal Highway Administration (FHWA) reported that national truck parking shortages are severe and widespread, and 75 percent of surveyed drivers reported having problems finding secure parking during the night (Federal Highway Administration, 2012). Resulting from such shortages and the issues associated with finding adequate parking are safety impacts to all highway users as a result of large trucks parking in unsafe locations (often due to drivers pushing their hours-of-service (HOS) limits to find safe and adequate parking). National HOS regulations limit drivers' time on the road to increase safety by limiting fatigue, thereby creating a need for adequate parking (Federal Motor Carrier Safety Administration, 2011). Furthermore, a lack of available parking leads to increased congestion at parking spots, drivers breaking regulations by continuing to drive past their allotted hours, and illegal parking. Congestion and lack of safe parking ultimately lead to safety concerns for transportation agencies and trucking industries throughout the country. In an attempt to better understand this issue, this study utilized the results of a recent truck driver survey administered in the Pacific Northwest. Understanding how truck drivers make parking decisions can provide insights into current parking problems and offer potential solutions for transportation agencies and trucking firms.

With that in mind, there have been recent efforts to address parking shortages throughout the transportation network. Funding programs to improve truck parking have been introduced, such as The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and Jason's Law. During the pilot program for SAFETEA-LU, 2008 to 2012, $231 million was requested from FHWA for parking-related projects. Of the $231 million

requested, just $34 million was released to support 20 projects (Office of Freight Management and Operations, 2015). Jason's Law allocated $1 billion from 2010 to 2015 for safe parking projects. Despite increased spending on projects, a recent FHWA survey indicated that 37 states still suffered from severe parking shortages (Federal Highway Administration, 2012).

Given the safety concerns associated with parking shortages, the projected increase in freight volumes, the current parking shortages reported, and the funding programs initiated, it is vital to determine the factors that lead to safe and adequate parking (from a driver's perspective) and to properly remedy them. It is hypothesized that the factors that influence truck parking shortages vary among different geographic regions of the United States. For this reason, the determination of unique regional factors is an important planning variable for project funding requests. Accordingly, this work utilized a survey directed at large truck drivers to uncover factors that lead to problems that drivers encounter in finding safe and adequate parking in the Pacific Northwest.

Recent studies have addressed truck parking availability and related problems for various regions across the United States. Pennsylvania conducted a survey to document the locations of trucks parked on highway shoulders and ramps. The factors found to contribute to drivers parking along shoulders, rather than in parking facilities, included personal safety, driver access, perceived capacity of the parking facility, local driver knowledge, and lack of capacity at parking facilities (Pennsylvania State Transportation Advisory Committee, 2007).

In South Dakota, a study focused on seven rest areas located along I-29 and I-90, where a common problem facing rest stops was determined. Specifically, rest area systems as a whole were nearing the end of their design life, and many did not comply with the Americans with Disabilities Act (ADA) or building code requirements. These inadequacies led to instances in

which truck drivers had to park at the point of entry (e.g., freeway ramps and shoulders) and walk to the visitor center to utilize the facilities, while many locations had poor heating, ventilating, and lighting systems (Felsburg Holt and Ullevig, 2014).

A New Jersey study identified common factors found to affect large truck parking. A key finding was that demand, likely associated with HOS regulations, was skewed toward overnight periods when most drivers slept and parking facilities were filled beyond capacity (Freight Initiative Committee, 2008). Similarly, a study conducted in Wisconsin concluded that fatigued truck drivers were unable to find parking because of HOS regulations; therefore, increasing parking demand at night exacerbated congestion at parking facilities (Adams et al., 2009). In some locations throughout New Jersey, rising real estate prices were found to impede parking capacity expansion because of alternative, higher-valued land uses near highways. As a result, truck-oriented operations were often unable to compete with lucrative land uses near highways (Freight Initiative Committee, 2008). Parking capacity issues were also evident from a study in Minnesota, which revealed that Interstate segments with high volumes of large trucks were closely correlated to congestion issues at rest areas (Maze et al., 2010); this was also the case for Adams et al. (2009).

The American Transportation Research Institute (ATRI) recently released a study with results from a Kansas Department of Transportation survey of more than 1,300 large truck drivers in Kansas. On the basis of the survey, it was determined that a majority of drivers spent, on average, more than 30 minutes searching for a location to park. The authors also noted that finding available parking was more difficult on weekdays than on weekends (Boris and Brewster, 2016).

As seen from the literature, there is a need to better understand truck parking issues from a driver's point of view. This is also evidenced by peer-reviewed research, as studies focusing on truck parking have been limited in number and have focused primarily on demand (Chatterjee and Wegmann, 2000; Gaber et al., 2005; Abdelgawad et al., 2011; Nourinejad et al., 2014; Bayraktar et al., 2015; Haque et al., 2016; Rosenfield et al., 2016). Therefore, this study focused on determining which factors directly lead to drivers encountering parking issues, as well as the effects of current parking-related issues and potential improvements on truck parking from a driver's perspective. This was accomplished by conducting a behavioral modeling technique, binary logistic regression, and aimed to fill the gap in the literature in that regard.

3.0 Data Collection

3.1 Introduction

Data used for this study consisted of survey responses from 201 large truck drivers who delivered goods in the Pacific Northwest; namely, Washington state, Oregon, and Idaho. The administered survey was part of an Oregon Department of Transportation project to address current truck parking issues along US-97 (shown in figure 3.1) (Hernández and Anderson, 2017). In the survey, the questions were used to determine driver characteristics (e.g., age, gender, etc.), thoughts on current parking issues related to freeway ramp and shoulder parking, important truck/rest stop features, and opinions regarding the effectiveness of certain truck/rest stop parking improvements. Of particular interest were questions related to issues in finding safe and adequate parking. To illustrate, figure 3.1 shows that more than half of the surveyed drivers encountered issues in finding safe and adequate parking. Furthermore, when asked what times of day, week, and year they had troubles finding safe and adequate parking, their responses closely corresponded to historical heavy vehicle crash trends (shown in figure 3.2). Therefore, to assess the factors that affect safe and adequate parking from a driver's perspective, a total of 134 indicator variables were generated from the driver survey responses; however, just 11 were found to be statistically significant. To illustrate the random sample of the survey, the origins of the surveyed drivers are presented in figure 3.3.

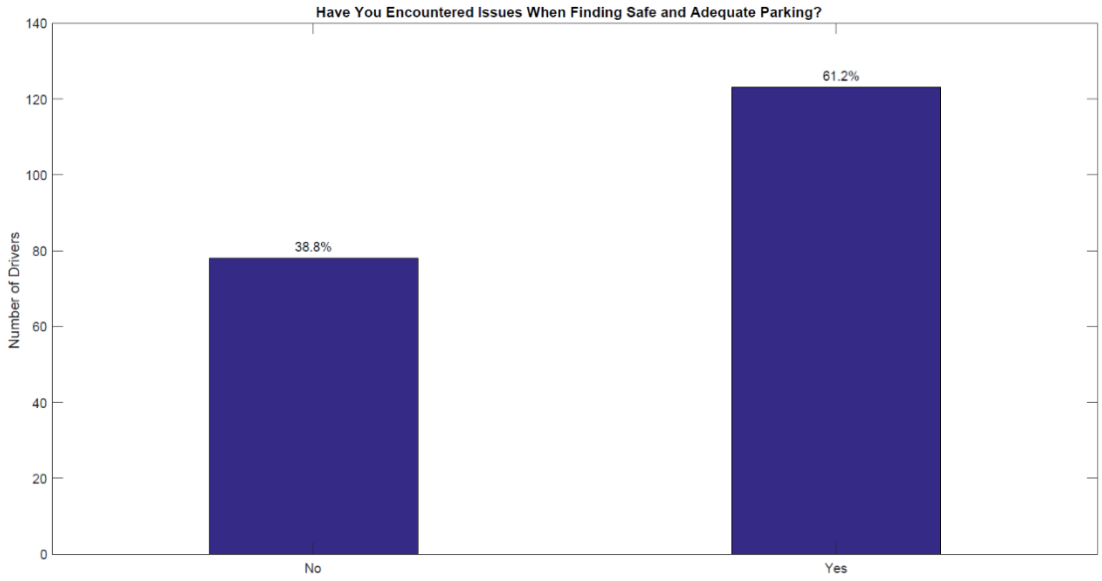

Figure 3.1 Percentage of drivers who have encountered issues with safe and adequate parking

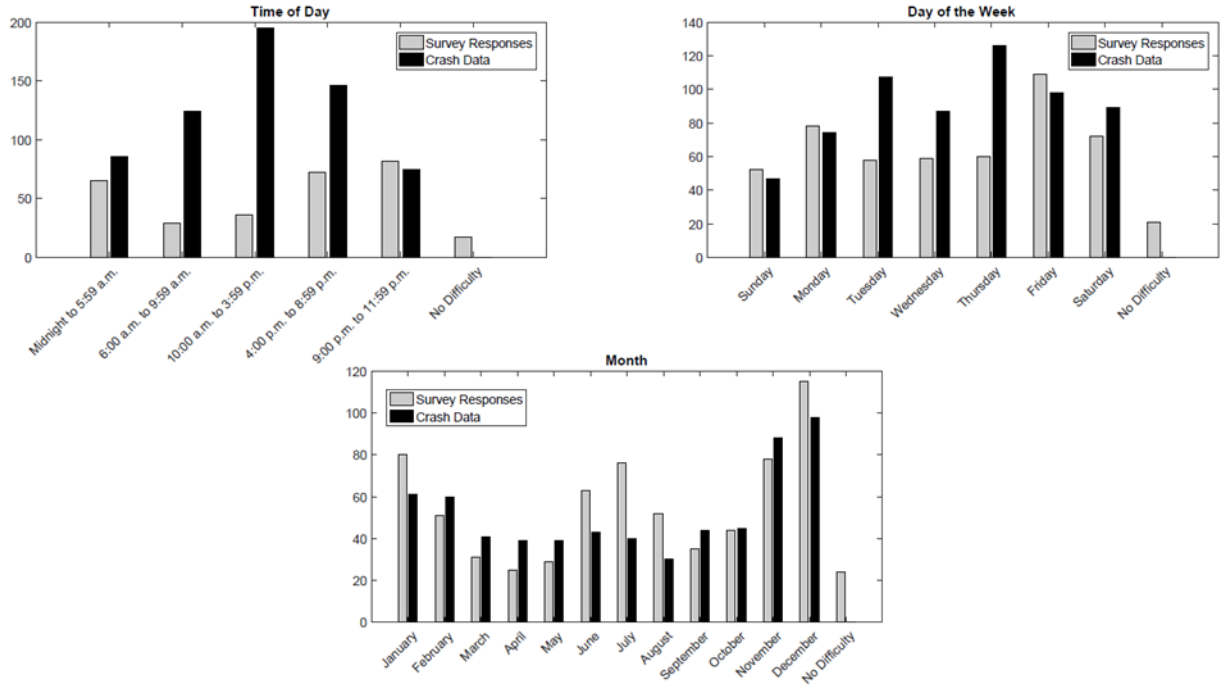

Figure 3.2 Difficulty parking by (a) Time of day, (b) Day of the week, and (c) Month

Figure 3.3 Origins of large truck drivers who deliver goods in the Pacific Northwest

3.2 Summary of the Survey Results

A representative stated-preference survey was designed and distributed to truck drivers who were destined for or who originated from the Pacific Northwest—namely, Washington state, Oregon, and Idaho. The stated-preference survey was administered through the Qualtrics platform of Oregon State University, and it was conducted over 16 consecutive days between August 17, 2017, and September 1, 2017. To eliminate the possibility of multiple entries from the same participant, IP addresses and user IDs were collected. The representative sample consisted of 201 participants, all truck drivers. Drivers of large trucks in the Pacific Northwest were asked several questions to provide their opinions of some factors that may affect safe and adequate parking from a driver's perspective.

In this study, participants were required to be truck drivers, to hold a commercial driver's license (CDL), to be at least 18 years old, and to be destined for or to originate from the Pacific Northwest. The survey comprised several sections: (1) socioeconomic characteristics, (2) business characteristics, (3) driving characteristics, (4) time-of-day operations, and (7) truck parking characteristics. For socioeconomic characteristics, participants were asked to provide demographic information such as age, gender, type of shipment carried, road safety training (whether they had received such training), and participation in team driving.

The second section, business characteristics, asked questions related to industry type, company operational characteristics, and average distances traveled. The driving characteristics section asked participants questions on their ability and confidence regarding driving a semi-truck, average speeds in various situations, roadway facility types, cell phone use while driving, frequency of lapses in concentration after driving for long periods, frequency of lane-changing to avoid traveling with other vehicles, and situations that pose the greatest safety hazards to drivers. For the accident characteristics, drivers were asked about their involvement in accidents, the number of accidents over a 5-year period, the types of accidents, and the weather conditions at the time of an accident.

With regard to time-of-day operations, drivers were asked about the time of day they started working and driving, the safest times of day to drive trucks, and the most difficult times of day, day of the week, and month to find safe and adequate truck parking. Questions were asked about fatigue management, including the effects of fatigue on adhering to hours-of-service requirements. Lastly, questions were asked about truck configurations.

Male drivers constituted 77 percent of the participants, whereas 23 percent were female. Roughly, 60 percent of drivers were between 20 and 39 years. As for the type of shipment,

nearly 82 percent of drivers' trips were truckload shipments. In terms of number of years the surveyed drivers had been driving large trucks, two-third (66 percent) of drivers had been driving a truck for 10 years or less. Forty-three percent of drivers revealed that they learned how to driver a semi-truck in a driving school. Furthermore, 87 percent of the respondents seemed to have a particular road safety training. In regard to team driving, the majority of drivers sometimes (31 percent), rarely (29 percent), and never (23 percent) participated in team driving. The drivers' history of accidents was been examined by asking them to reveal how many accidents they had been involved in over the last five years. Roughly, 76 percent of drivers report that they had not had any accidents. Regarding actions that may distract drivers, 45 percent of drivers stated that they used a cell phone while driving.

4.0 Analytical Framework

Questions related to issues in finding safe and adequate parking were used to estimate an econometric model that helped us highlight the factors that impact safe and adequate parking from a driver's perspective. Below is a description of the analytical process.

Logit-based models have been applied to several research topics, such as large truck safety (Altwaijri et al., 2012; Islam and Hernandez, 2013; Pahukula et al., 2015; Anderson and Hernandez, 2017; Uddin and Huynh, 2017) and the evaluation of park-n-ride facilities (Cornejo et al., 2014). In the case of the current study, drivers encountering troubles while finding safe and adequate parking would be binary. Accordingly, a binary behavior model was applied.

As previously stated, because of the binary nature of the selected response variable, a binary choice modeling method was applied: binary logistic regression. (A binary probit approach could also have been applicable; however, both models were tested and the binary logit model provided a better overall fit.) The two possible outcomes were represented by the response variable: 1 if a driver had trouble finding safe and adequate parking, and 0 otherwise (i.e., the driver had no issues finding safe and adequate parking). Therefore, the following binary logit formulation was used to determine the probability that the outcome would take on the value 1 as a function of covariates (Washington et al., 2011):

$$P_n(i) = \frac{e^{(\hat{\beta})}}{1+e^{(\hat{\beta})}} \quad \text{where} \quad \hat{\beta} = \beta_0 + \beta_1 X_{1,n} + \cdots + \beta_i X_{i,n} \tag{4.1}$$

where

$P_n(i)$ is the probability that a large truck driver encounters trouble finding safe and adequate parking, or the probability that a driver believes safe and adequate parking is not attainable (e.g., the outcome takes on the value 1);

$\hat{\beta}$ is a vector of estimated parameters; and,

X is a vector of explanatory variables (i.e., indicator variables based on responses from the survey) used to determine the outcome probability of $P_n(i)$ being equal to 1.

However, as is the case with most data sets, heterogeneity (variation) was likely present within the existing variables. For example, driver experience was likely to impact specific factors (e.g., ability to maneuver in a parking facility) but was not captured in the data. Likewise, unobserved factors can affect thoughts on preferred methods of real-time information (e.g., age, experience with types of technology, etc.) yet were also not captured in the data. Therefore, in an attempt to account for this data heterogeneity by allowing observation-specific variation, a random parameters technique was applied, and Eq. (4.1) was written as follows (Washington et al., 2011):

$$P_n(i|\varphi) = \int_x \frac{e^{(\hat{\beta})}}{1+e^{(\hat{\beta})}} f(\hat{\beta}|\varphi) d\hat{\beta} \quad (4.2)$$

where $P_n(i|\varphi)$ is the weighted outcome probability of $P_n(i)$ taking on the value 1, conditional on $f(\hat{\beta}|\varphi)$, where $f(\hat{\beta}|\varphi)$ is the density function of $\hat{\beta}$ with distributional parameter φ.

The density function, $f(\hat{\beta}|\varphi)$, is given a distribution defined by the analyst (e.g., normal, uniform, etc.) and is what allows parameters to vary across observations, which permits $\hat{\beta}$ to account for observation-specific variations of the effect of X on $P_n(i|\varphi)$ (Washington et al., 2011). The density function $f(\hat{\beta}|\varphi)$ is typically specified to be normally distributed; still, several distributions are tested for statistical significance during the analysis. For this work, the normal, uniform, and triangular distributions were tested; however, only the normal distribution was found to have statistically significant standard deviations.

To assess variable impact, inferences from marginal effects were used. Marginal effects measure the impact on the response variable due to a one-unit increase in an explanatory variable while holding all other variables constant (i.e., equal to their means). For indicator variables, the variable type used in the current study, this was the difference in probability as indicator variable X_k changed from zero to one while all other variables remained equal to their means (Greene, 2012):

$$ME_{X_k}^{P_n(i)} = \text{Prob}[P_n(i) = 1 \mid X_k = 1] - \text{Prob}[P_n(i) = 1 \mid X_k = 0] \quad (4.3)$$

5.0 Estimation Results and Discussion

As previously discussed, 11 variables were found to be statistically significant in determining safe and adequate truck parking from a driver's perspective. Best fit model specifications and marginal effects are displayed in table 5.1. Of the 11 significant variables, two were found to have estimated random parameters (e.g., variation across observations); the estimated constant (β_0) was also found to be random and normally distributed. To discuss and infer model estimations properly, the discussion will focus on the characteristics found to directly increase the likelihood of finding safe and adequate parking, factors found to lead to unsafe parking from a driver's perspective (i.e., thoughts on freeway ramp and shoulder parking), important features that impact finding safe and adequate parking according to drivers, the effectiveness of potential improvements based on the belief of drivers, and the effects of real-time information on safe and adequate parking from the viewpoint of drivers.

Table 5.1 Random parameters binary logit model specifications and marginal effects

Variable	Coefficient	*t*-statistic	Marginal Effect	*t*-statistic
Constant	1.29	4.67		
(Standard Deviation of Parameter, Normally Distributed)	***(0.45)***	***(2.05)***		
Shipment Type (1 if Less-Than-Truckload, 0 Otherwise)	-1.42	-3.14	-0.32	-3.31
Probable Reason For Parking on Freeway On/Off Ramps (1 if No Nearby Parking Facility)	-1.00	-2.93	-0.23	-3.20
Important Features When Choosing Where to Park (1 if Showers, 0 Otherwise)	-1.25	-2.13	-0.28	-2.15
Helpful Real-Time Information (1 if Number of Available Truck Parking Spaces at Upcoming Facilities)	-0.93	-2.19	-0.21	-2.29
Neither Effective Nor Ineffective Truck Parking Improvements (1 if Amenity Improvement, 0 Otherwise)	-1.23	-2.06	-0.28	-2.08
Ineffective Truck Parking Improvements (1 if Time Limit Enforcement, 0 Otherwise)	0.84	2.43	0.19	2.30
Driver Age (1 if Between 60 and 69 Years, 0 Otherwise)	-1.30	-1.89	-0.29	-1.95
Improbable Reason for Parking on Freeway On/Off Ramps (1 if Difficulty Maneuvering Around Parking Lots, 0 Otherwise)	-0.62	-1.72	-0.14	-1.76
(Standard Deviation of Parameter, Normally Distributed)	***(3.42)***	***(4.72)***		
Neither Important nor Unimportant Features When Choosing Where to Park (1 if Internet Connections, 0 Otherwise)	-0.42	-1.11	-0.09	-1.14
Preferred Method to Receive Real-Time Information on Truck Parking Availability (1 if GPS, 0 Otherwise)	1.21	2.72	0.27	2.62
(Standard Deviation of Parameter, Normally Distributed)	***(2.65)***	***(4.07)***		
Time of Week That is Most Difficult to Find Safe and Adequate Parking (1 if Weekday, 0 Otherwise)	2.22	2.31	0.50	2.29
Model Summary				
Number of Observations	201			
Log-Likelihood at Zero (Constant Only)	-134.24			
Log-Likelihood at Convergence	-106.32			
McFadden Pseudo R^2	0.21			

5.1 Characteristics Directly Affecting the Likelihood of Finding Safe and Adequate Parking

The characteristics found to directly affect drivers encountering issues with safe and adequate parking included the type of shipment, the age of the driver, and the days of the week. With regard to shipment type, drivers delivering less-than-truckload (LTL) shipments were less likely to encounter problems in finding a safe and adequate location to park. According to marginal effects, drivers with LTL shipments had a 0.32 lower probability of encountering parking issues. This is likely attributable to the length of their haul, as LTL shipments often

range between 200 and 600 miles, and drivers are more easily able to make their deliveries within HOS regulations (Stephens, 2017).

Also decreasing the likelihood of encountering issues in finding safe and adequate locations to park were drivers' ages. Marginal effects showed that drivers ages 60 to 69 had a 0.29 lower probability of encountering parking troubles. This might be explained by the amount of experience drivers in this age group have; that is, life-long drivers may interpret "safe and adequate" parking differently. It is possible that these drivers may consider any open space, whether a dedicated parking location or not, safe and adequate. For example, if a driver had been parking on freeway shoulders or on/off ramps over a substantial period of time with no troubles, s/he might perceive it as safe and adequate.

Finally, having trouble finding safe and adequate parking was found to be more likely on a weekday. Marginal effects suggested a 0.50 higher probability of encountering problems in looking for safe and adequate parking on a weekday. This was the largest impact variable, and Boris and Brewster (2016) also found that finding parking was more difficult on weekdays. This result is intuitive, given that the largest total traffic volumes and large-truck volumes are seen on weekdays. When demand for parking is higher because of larger traffic volumes, there is an inherent shortage of safe and adequate parking. Although work has occurred to address delivery of goods during non-peak hours, mitigating large-truck volumes during peak volume hours is still an ongoing process.

5.2 Characteristics Leading to Unsafe and Inadequate Parking

To gain a better understanding of parking on freeway ramps and shoulders, and its effect on troubles in finding safe and adequate parking, drivers were asked what probable (or

improbable) reasons would lead to parking in those locations. For example, if no nearby parking facilities was a probable reason for parking on freeway ramps and shoulders, then drivers believed they were less likely to encounter problems. In other words, if there was no nearby parking facility, drivers might decide to park in another location they deemed safe and adequate. If this was the case, then these drivers would not report that they had experienced parking issues because they believed they were parking in a safe and adequate location. In fact, marginal effects showed that drivers who thought that the unavailability of nearby parking facilities was a probable reason for parking on freeway ramps and shoulders had a 0.23 lower probability of experiencing issues finding a safe and adequate place to park. Again, this is likely due to drivers genuinely believing that their alternative parking location (e.g., freeway ramps) was safe and adequate. Parking in these locations has also been found to decrease truck parking utilization (Haque et al., 2016).

For the next significant factor—difficulty maneuvering in parking lots as an improbable reason for parking on freeway ramps and shoulders—the estimated parameter (β) was found to be random and normally distributed on the basis of the significance of the standard deviation. With a mean of -0.62 and a standard deviation of 3.42, the estimated parameter mean for difficulty maneuvering around parking lots was greater than zero for 42.8 percent of drivers and less than zero for 57.2 percent of drivers. That is to say, 42.8 percent of drivers believed that difficultly maneuvering around parking lots led to encountering problems in finding safe and adequate parking; however, 57.2 percent of drivers believed differently. The non-homogenous nature seen here may be a result of driver experience or truck size. For instance, a proportion of drivers with a significant amount of experience would be likely to have minimal issues in maneuvering their truck for parking (e.g., a driver who had driven the same truck for many

years), whereas some drivers might have operated a truck that was simply too big to maneuver safely in certain parking locations.

5.3 Important Features Impacting the Likelihood of Finding Safe and Adequate Parking

Two features were found to be statistically significant in determining the likelihood of experiencing problems in looking for safe and adequate parking. The first feature, showers, was an important feature to drivers and decreased the likelihood of experiencing issues in trying to find a safe and adequate area to park. Marginal effects showed a 0.28 lower probability of encountering problems. This result may seem counterintuitive, but if drivers are willing to park at any location with enough space for their truck and showers are present, they may believe they are parking safely and adequately. Unfortunately, there is subjectivity among drivers in regard to "safe and adequate" parking, and if space is available and showers are present, some drivers will likely think they are parking in a safe and adequate location. Just 8 percent of the surveyed drivers indicated that showers were an important feature; therefore the percentage of drivers who thought such was presumably low.

The second feature, Internet connections, was neither important nor unimportant to drivers, and marginal effects indicated a 0.09 lower probability of undergoing troubles in finding safe and adequate parking. In this case, given that Internet connections were found to be neither important nor unimportant, drivers were likely to park at the nearest location with available spaces; therefore, encountering parking issues was reported to be less likely. This may be attributed to the widespread use of mobile phones with unlimited data plans and, as a result, no serious need for Internet connections.

5.4 Effectiveness of Potential Improvements on Safe and Adequate Parking

In looking at the effectiveness of potential truck parking improvements from a driver's point of view, two potential improvements were found to statistically affect drivers' perception of being able to find safe and adequate parking. Of the potential improvements, drivers thinking that amenity improvements would be neither effective nor ineffective was significant and decreased the likelihood of experiencing parking issues. This finding might be linked to drivers belief that current amenities were fine and that an improvement would not affect their parking decision; therefore, experiencing parking issues would be less likely. Furthermore, marginal effects showed a 0.28 lower probability of having problems in looking for a parking location if a driver believed that amenity improvements were neither effective nor ineffective.

The potential improvement of time limit enforcement being ineffective was found to increase the likelihood of experiencing problems in finding parking, and marginal effects indicated a 0.19 higher probability of such. A possible explanation could be that drivers preferred to park and rest on their own time schedule and did not want to be forced to leave before they were rested. This would be especially true if drivers chose to park at a location where the time limit was less than the required rest time to meet HOS regulations, but the chosen location was the only safe and adequate parking location for several miles. This result suggests that better than enforcing time limits would be to extend them to meet required rest times. In addition, this would mitigate the number of drivers exceeding their allowable drive time by allowing them to park at the nearest truck stop or rest area.

5.5 Effects of Real-Time Information on Safe and Adequate Truck Parking

With regard to real-time information and the impact it has on helping drivers to find safe and adequate parking, information about the number of available truck parking spaces at

upcoming facilities in real time was statistically significant. Real-time information on the number of available truck parking spaces at upcoming facilities decreases the likelihood of encountering parking troubles, and marginal effects showed a 0.21 lower probability of encountering troubles. This result is fairly intuitive, as drivers can prepare for parking while driving. Therefore, drivers likely believed they were less likely to have trouble finding safe and adequate parking. Without real-time information, drivers must exit the highway and hope there is an available parking space; if not, they are forced back on the highway to find the next available space. This uncertainty can lead to drivers past their HOS threshold being on the highway, likely fatigued, and searching for an adequate place to park.

Turning to the preferred method of receiving real-time information about truck parking availability, according to drivers, GPS was found to be statistically significant. Furthermore, the estimated parameter for GPS being the preferred method to receive real-time information was random and normally distributed. A mean of 1.21 and a standard deviation of 2.65 imply that the estimated parameter mean for GPS was less than zero for 32.4 percent of drivers and greater than zero for 67.6 percent of drivers. In other words, 32.4 percent of drivers believed that encountering troubles in looking for a safe and adequate parking place was less likely, while 67.6 percent of drivers believed it to be more likely. The heterogeneous effects seen here may be a result of not all drivers preferring GPS for receiving real-time parking information. For instance, roughly one-half of the surveyed drivers were younger than 40, and the randomness in this estimated parameter may be accounted for by drivers who believed that a more useful way of receiving real-time information was through a smart phone application. On the other hand, older drivers may have preferred to have this information relayed via GPS or radio. This finding

suggests that although GPS would help a proportion of drivers find safe and adequate parking, a percentage of drivers would not benefit from real-time information disseminated via GPS.

6.0 Summary

This study utilized a survey issued to large truck drivers who deliver goods in the Pacific Northwest to gain a better understanding of safe and adequate truck parking, and its associated contributing factors, from the viewpoint of drivers. Because of data heterogeneity, a random parameters binary logit approach was applied to produce the most accurate estimates and to make appropriate inferences. With that in mind, heterogeneity within two variables was found: particularly, difficulty maneuvering around parking lots being an improbable reason for parking on freeway ramps and shoulders, and GPS being the preferred method to receive real-time information on truck parking availability.

Through the analysis, three factors were determined to directly affect safe and adequate parking: LTL shipments, drivers between the ages 60 to 69, and weekdays. Other than weekdays, these factors were less likely to result in troubles finding safe and adequate parking, suggesting that future truck parking studies should focus on truckload shipments and younger age groups. As for the remaining significant factors that led to drivers believing (or not believing) that they would experience issues in looking for a safe and adequate parking place, subjectivity was present and would need to be mitigated in future truck parking research. Take, for example, no nearby parking facilities resulting in drivers being less likely to encounter parking issues; this is entirely contingent on a driver's perspective of safe and adequate parking. Therefore, such subjectivity needs to be properly accounted for in future work. Lastly, providing real-time information to drivers appears to have the potential to improve the ability of drivers to find safe and adequate parking and warrants future attention, with a specific focus on the most beneficial method to deliver the information.

In summary, the current study provided an empirical method to determine factors associated with safe and adequate truck parking troubles. This method allows the analyst to identify key factors on the basis of information provided by the drivers, as well as provide insights to state agencies and the trucking industry with which they can further their attempts to implement safe and adequate truck parking across the United States. Ultimately, safe and adequate truck parking can save a substantial number of lives by mitigating related safety concerns for all users of the nation's highway infrastructure.

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APPENDIX

Truck Parking Survey: Truck Drivers

Q0 EXPLANATION OF RESEARCH Project Title: Truck Parking: An Emerging Safety Hazard to Highway Users
Principal Investigator: Salvador Hernandez, PhD
Sponsor: Oregon Department of Transportation (ODOT) Version
Date: November 9, 2015
Purpose: You are being asked to take part in a research study. The purpose of this research study is to give guidance and to assist the Oregon Department of Transportation (ODOT) in important policy decisions with regards to truck parking issues in the state. The results of the study will be used for the graduate students dissertation.
Activities: The study activities include the administration of a survey designed to gather information regarding how and why drivers choose their parking locations and identify driver behavioral response to parking shortages.
Time: Your participation in this study will last about 10 minutes.
Confidentiality: It is possible that others could learn that you participated in this study but the information you provide will be kept confidential to the extent permitted by law.
Voluntary: Participation in this study is voluntary. If you choose to participate, answering all questions is required, and all questions must be answered in order for the responses to be included in the study results.
Study contacts: If you have any questions about this research project, please contact: Dr. Salvador Hernandez at sal.hernandez@oregonstate.edu. If you have questions about your rights or welfare as a participant, please contact the Oregon State University Institutional Review Board (IRB) Office, at (541) 737-8008 or by email at IRB@oregonstate.edu
Dr. Sal Hernandez Assistant Professor School of Civil and Construction Engineering Oregon State University 101 Kearney Hall (Physical Address) Corvallis, OR 97331-3212 Phone: (541) 737-1757 email: sal.hernandez@oregonstate.edu

Q0 SECTION A: Background

Q23 Do you drive a commercial grade truck for your profession?

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To End of Block

Q1 Do you pickup or deliver goods in the Pacific Northwest (California, Idaho, Oregon, Washington, or British Columbia)?

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To End of Block

Q2 Are you male or female?

- ❍ Male (1)
- ❍ Female (2)

Q3 Which of the following age category best describes you:

- ❍ 20 to 29 (1)
- ❍ 30 to 39 (2)
- ❍ 40 to 49 (3)
- ❍ 50 to 59 (4)
- ❍ 60 to 69 (5)
- ❍ 70 or greater (6)

Q4 How long have you been a truck driver? (Please enter the number of years)

Q5 What type of company do you work or contract for?

- ❍ For-hire (1)
- ❍ Private carriage (2)
- ❍ Both for-hire and private (3)
- ❍ Don't know/refuse (4)

Q6 On average, what type of shipments do your trips consist of?

- ❍ Less-than-truckload (1)
- ❍ Truckload (2)
- ❍ Parcel (3)
- ❍ Don't know/refuse (4)

Q0 SECTION B: Parking Decisions and Preferences

Q7 Do you participate in team driving?

- ❍ Never (1)
- ❍ Rarely (2)
- ❍ Sometimes (3)
- ❍ Often (4)
- ❍ All of the Time (5)

Q8 When it comes to deciding where to stop to park

- ❍ I typically make that decision (1)
- ❍ My company (e.g., dispatcher, etc.) makes that decision (2)
- ❍ Other, please specify (3) _____

Q9 When required to rest, have you experienced any problems finding a safe and adequate location to park your truck?

- ❍ Yes (1)
- ❍ No (2)

Q10 In your experience, what times of the day have you found to be the MOST difficult in finding safe truck parking? (Please select all that apply)

- ❑ Early Morning (Midnight - 5:59 AM) (1)
- ❑ Morning (6:00 AM - 9:59 AM) (2)
- ❑ Mid-day (10:00 AM - 3:59 PM) (3)
- ❑ Afternoon (4:00 PM - 8:59 PM) (4)
- ❑ Evening (9:00 PM - 11:59 PM) (5)
- ❑ I don't have difficulty (6)

Q11 In your experience, what days of the week have you found to be the MOST difficult in finding safe truck parking? (Please select all that apply)

- ❑ Sunday (1)
- ❑ Monday (2)
- ❑ Tuesday (3)
- ❑ Wednesday (4)
- ❑ Thursday (5)
- ❑ Friday (6)
- ❑ Saturday (7)
- ❑ I don't have difficulty (8)

Q12 Which months of the year have you found to be the MOST difficult in finding safe truck parking? (Please select all that apply)

- ❑ January (1)
- ❑ February (2)
- ❑ March (3)
- ❑ April (4)
- ❑ May (5)
- ❑ June (6)
- ❑ July (7)
- ❑ August (8)
- ❑ September (9)
- ❑ October (10)
- ❑ November (11)
- ❑ December (12)
- ❑ I don't have difficulty (13)

Q13 In your opinion, Why do you think ramps and shoulders are sometimes used for truck parking? Please rank the following on a scale of 1-9, where 1 is the "most probable reason" and 9 the least.

_____ No nearby parking facility (1)
_____ Nearby truck stops or rest areas are full (2)
_____ Nearby parking spaces have time limits that are too short (3)
_____ Difficulty maneuvering around parking lots (4)
_____ Empty nearby parking spaces are blocked by other vehicles (5)
_____ The ramp/shoulder is convenient for getting back on the road (6)
_____ Better lighting on ramp/shoulder than in lot (7)
_____ Less likely to be bothered by strangers (e.g., drug dealers, prostitutes) (8)
_____ Other, please specify (9)

Q14 Please rate how IMPORTANT the following features are to you when you park at a truck stop or rest area

	Not at all Important (1)	Very Unimportant (2)	Neither Important nor Unimportant (3)	Very Important (4)	Extremely Important (5)
Convenience to highway (1)	❍	❍	❍	❍	❍
Repair facilities (2)	❍	❍	❍	❍	❍
Fuel (3)	❍	❍	❍	❍	❍
Restrooms (4)	❍	❍	❍	❍	❍
Showers (5)	❍	❍	❍	❍	❍
Well-lighted parking lot (6)	❍	❍	❍	❍	❍
Security presence (7)	❍	❍	❍	❍	❍
Convenience store (8)	❍	❍	❍	❍	❍
Restaurants (9)	❍	❍	❍	❍	❍
Vending machines (10)	❍	❍	❍	❍	❍
Travel info (info on kiosks, etc.) (11)	❍	❍	❍	❍	❍
Internet connections (12)	❍	❍	❍	❍	❍
Please select "Very Important" (13)	❍	❍	❍	❍	❍
Entertainment facilities (e.g., Arcade, movies) (14)	❍	❍	❍	❍	❍
Other, please specify (15)	❍	❍	❍	❍	❍

Q0 SECTION C: Parking Solutions

Q15 What type of real-time information on truck parking availability would help you plan in advance your stops while you drive? (Please select all that apply.)

- ❍ Location of truck parking facilities along planned travel route(s) (1)
- ❍ Number of truck parking spaces available at upcoming parking facilities (e.g., Rest Areas and Truck Stops) (2)
- ❍ Time limits on upcoming truck parking spaces at parking facilities (e.g., Rest Areas and Truck Stops) (3)
- ❍ Features (e.g., food, fuel, etc.) that are available at upcoming parking facilities (4)
- ❍ Other, please specify (5) _____

Q16 How would you like to receive the information on truck parking availability?

- ❍ Smart phone app (1)
- ❍ Global Position System (GPS) (2)
- ❍ Radio in vehicle (e.g., CB, low-power FM, DSRC (Dedicated Short Range Communication)) (3)
- ❍ Other, please specify (4) _____

Q17 Below is a list of possible truck parking improvements, in your view how EFFECTIVE would these improvements be in improving your truck parking experience.

	Very Ineffective (1)	Ineffective (2)	Neither Effective nor Ineffective (3)	Effective (4)	Very Effective (5)
Improve lighting at parking facilities (1)	❍	❍	❍	❍	❍
Increase security presence at parking facilities (2)	❍	❍	❍	❍	❍
Landscape to minimize hiding places for criminals/criminal activity (3)	❍	❍	❍	❍	❍
Improve amenities at rest areas (4)	❍	❍	❍	❍	❍
Build more truck stop parking spaces (5)	❍	❍	❍	❍	❍
Build more rest area parking spaces (6)	❍	❍	❍	❍	❍
Separate truck, car, and RV parking (7)	❍	❍	❍	❍	❍
Use car parking for truck parking during peak overnight hours (8)	❍	❍	❍	❍	❍
Enforce time limits on truck parking (9)	❍	❍	❍	❍	❍
Eliminate time limits on truck parking (10)	❍	❍	❍	❍	❍
Improve parking layout/configuration (e.g., more diagonal pull-through) (11)	❍	❍	❍	❍	❍
Improve signs and roadway information for parking facilities (12)	❍	❍	❍	❍	❍

Educate drivers/dispatchers about planning parking stops before trip (13)	❍	❍	❍	❍	❍
Real-time information on parking space availability (14)	❍	❍	❍	❍	❍
Adopt standard spacing between rest areas (15)	❍	❍	❍	❍	❍
Please select "Very Ineffective" (16)	❍	❍	❍	❍	❍
Provide alternative parking (e.g., at weigh stations, Park-N-Ride, private parking lots) (17)	❍	❍	❍	❍	❍
Stop enforcement officers from waking driver (18)	❍	❍	❍	❍	❍
Other, please specify (19)	❍	❍	❍	❍	❍

Q18 Do you have any other comments, questions, or concerns you would like to share?