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Perceived safe and adequate truck parking: A random parameters binary logit analysis of truck driver opinions in the Pacific Northwest

Jason C. Anderson [a], Salvador Hernandez [b,*], Eric L. Jessup [c,d], Eric North [a]

[a] School of Civil and Construction Engineering, Oregon State University, 211 Kearney Hall, Corvallis, OR 97331-3212, United States
[b] Civil and Construction Engineering, Oregon State University, United States
[c] School of Economic Sciences, Washington State University, United States
[d] Freight Policy Transportation Institute, Washington State University, United States

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ABSTRACT

This paper focuses on the availability of parking for freight vehicles, with a specific focus on being able to find safe and adequate parking (i.e., a designated parking location for large trucks) along a primary freight corridor in Oregon. This is achieved through the use of a truck driver survey regarding their experiences related to the availability of safe and adequate parking. The survey is geographically focused on drivers and freight activity throughout the Pacific Northwest, as to better infer on truck parking along the study corridor. The data and information collected are then utilized to estimate a binary outcome (logit) model to evaluate how different factors, obtained from the driver survey, impact the likelihood of finding safe and adequate parking from the perspective of the driver. Of 134 indicator variables, 11 factors are found to be statistically significant and provide insights into what impacts or affects the probability that a driver will encounter problems finding safe and adequate parking. Results show that drivers of less-than-truckload (LTL) shipments, weekend shipments, and older drivers have significantly fewer challenges finding safe and adequate parking. Findings from the current study can be used to better guide efforts in Oregon, and across the country, in regard to safe and adequate truck parking.

1. Introduction

The limited availability of adequate parking is an ongoing issue for drivers of large trucks 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% of the surveyed drivers reported having problems finding secure parking during the night (Federal Highway Administration, 2012). As a result of such shortages and the issues associated with finding adequate parking, there are intrinsic safety impacts to all highway users due to large trucks parking in unsafe locations (this is often due to drivers pushing their hours-of-service (HOS) limits to find safe and adequate parking). National HOS regulations limit drivers' time

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* Corresponding author.
E-mail addresses: anderjas@oregonstate.edu (J.C. Anderson), sal.hernandez@oregonstate.edu (S. Hernandez), eric_jessup@wsu.edu (E.L. Jessup), northe@oregonstate.edu (E. North).

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on the road, in an attempt to increase safety by limiting fatigue, thereby creating a need for adequate parking (Federal Motor Carrier Safety Administration, 2011). Further, 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 leads to safety concerns for transportation agencies and trucking industries throughout the country. In an attempt to better understand this issue, the current study utilizes the results of a recent truck driver survey administered in the Pacific Northwest. Understanding how truck drivers make these parking decisions can provide insights on 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, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and Jason's Law. During the pilot program of 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 37 states still suffer 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 funding programs initiated, it is vital to determine those factors which lead to difficulty finding safe and adequate parking (from a driver's perspective) and to adequately address them. Previous works have shown the importance of understanding user perception in regards to mode choice and its impact on adopting measures to properly increase ridership among a given mode (Paulley et al., 2006; Commins and Nolan, 2011; Hernández and Witter, 2015). Therefore, in the current study, understanding how drivers perceive safe and adequate parking can assist state and federal agencies in planning and adopting the appropriate solutions for truck parking shortages.[1] It is hypothesized that varying geographic regions of the United States have different factors that influence truck parking shortages. For this reason, determining unique regional factors is an important planning variable for project funding requests. Accordingly, this work utilizes a survey directed to drivers of large trucks to uncover factors that lead to drivers encountering problems finding safe and adequate parking (i.e., designated parking location for large trucks) in the Pacific Northwest region of the United States.

2. Background

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

In South Dakota, there was a study that 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 are nearing the end of their design life, and many do not comply with the Americans with Disabilities Act (ADA) or building code requirements. These inadequacies lead to instances where truck drivers must park at the point of entry (e.g., freeway ramps and shoulders) and walk to the visitor center to utilize the facilities (Felsburg Holt and Ullevig, 2014). In addition, many of these locations possess poor heating, ventilating, and lighting systems (Felsburg Holt and Ullevig, 2014).

A recent New Jersey study identified common factors that affect large truck parking. A key finding was that the demand, likely associated with HOS regulations, is skewed toward overnight periods when most drivers sleep and parking facilities are filled beyond capacity (Freight Initiative Committee, 2008). Similarly, a study conducted in Wisconsin concluded that fatigued truck drivers are unable to find parking due to HOS regulations; therefore, increasing parking demand at night and exacerbating congested parking facilities (Adams et al., 2009). In some locations throughout New Jersey, rising real estate prices impede parking capacity expansion due to alternative, higher-valued land-uses near highways. As a result, truck-oriented operations are 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 revealing that interstate segments with high volumes of large trucks are 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 1300 drivers of large trucks in Kansas. Based on the survey, it was determined that a majority of drivers spend, on average, more than 30 min searching for a location to park; it was also noted that finding available parking is 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 seen in peer-reviewed research, in which studies that focus on truck parking are quite sparse and focus 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). As such, this study focuses on what factors directly lead to drivers

[1] It is important to note that the factors identified in this work are based on driver perceptions (i.e., not factors directly leading to troubles finding safe and adequate parking).

encountering parking issues, as well as the effect of current parking related issues and potential improvements on truck parking from a driver's persepctive. This is completed through a behavioral modeling technique, binary logistic regression, and aims to fill the gap in the literature in that regard.

3. Empirical settings

Data used for this study consists of survey responses from 201 drivers of large trucks that deliver 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 the current truck parking issues along US-97 (shown in Fig. 9) (Hernández and Anderson, 2017).[2] The stated-preference survey was administered through Oregon State University utilizing the Qualtrics platform, in which only drivers that were destined to or originating in the Pacific Northwest were to participate (i.e., only drivers that deliver or pickup goods in the Pacific Northwest). The survey link was then sent to drivers for them to complete on their own time. The survey process, including developing the survey instrument and administering it through Qualtrics, took several months to reach a population size in which statistical inferences can be made with a high level of confidence relative to the population. The referenced population size refers to a number of observations in which inferences can be made with a specific level of confidence (Smith, 2013):

$$N = \frac{(z - \text{score})^2(\sigma)(1-\sigma)}{(\text{Margin of Error})^2} \tag{1}$$

where z – score is equal to 1.645 for 90% confidence, σ the standard deviation and equal to 0.5 (most conservative number and ensures the sample size will be adequate), and margin of error is the acceptable margin of error (i.e., the difference between 1 and 0.90). For the purpose of resource allocation and time, a 90% confidence level was chosen. As a result, using Eq. (1), the required sample size for a 90% confidence level is 68. In the present study, a total of 201 completed surveys are used. This sample size is substantially larger than the required size for 90% confidence; however, it is not quite large enough for 95% confidence (385 observations).

In the survey, questions were used to determine driver characteristics (e.g., age, gender, etc.), thoughts on current parking issues related to freeway ramp and shoulders, important truck stop and rest area features, and opinions regarding the effectiveness of certain truck stop or rest area parking improvements. To show driver characteristics, Fig. 1 displays driver gender, driver age, and the number of years driving a truck. As shown, more than 80% of the surveyed drivers were male. Further, nearly one-half of the surveyed drivers were under the age of 40 (23% from 20 to 29 years of age and 29% from 30 to 39 years of age). Lastly, the majority of surveyed drivers have been driving a truck for five years or less (39%), while 26% of the surveyed drivers have been driving a truck from 6 to 10 years. However, during analysis, the only driver characteristic found to be statistically significant were drivers 60 to 69 years of age (the lowest proportion of drivers, in terms of age, at 9%).

Next, to gain a better understanding of the company- and shipment-type characteristics of the surveyed drivers, see Fig. 2. The disparity between company types is not too significant, although the majority of respondents work for a private carriage (36%). That said, greater than two-thirds of the respondents (34%) and one-quarter of respondents (28%) stated they work for both for-fire and private, and for-hire, respectively. During analysis, no company-type characteristic was found to be statistically significant. With regard to shipment type, more than three-quarters (78%) of the surveyed drivers stated that their trips consist of truckload shipments. This variable, surprisingly, was not found to be statistically significant in the modeling process being that they travel longer distances and are more prone to require rest. Of the shipment characteristics, less-than-truckload (LTL) was found to be statistically significant and just 15% of the surveyed drivers stated that their trips consist of LTL (see Fig. 3.).

The next variables, in which both were found to be significant during analysis, are the variables regarding real-time information. The first was the type of real-time information wanted by the surveyed drivers, the number of available parking spaces at upcoming parking facilities. Of the types of real-time information, this was the one wanted by the majority of drivers (39%), with the location of truck parking facilities along the planned route second (33%). Regarding methods to receive real-time information, the method with the largest number of response was a smart phone application at 56%; however, this was not found to be statistically significant. The method found to be statistically significant was a global positioning system (GPS), in which 31% of surveyed drivers indicated this would be the preferred method to disseminate parking information. In addition, as discussed in Section 5, this factor was also found to be heterogeneous across drivers.

The following set of questions asked drivers to rank specific conditions from least probable to most probable or least important (i.e., unimportant) to most important. The first of these questions include probable/improbable reasons for freeway ramp and shoulder parking. In particular, Fig. 4 shows the responses in regards to no nearby parking facilities and difficulty maneuvering as probable reasons for freeway ramp and shoulder parking. As shown in Fig. 4a, more than 50% of the surveyed drivers stated that no nearby parking facility is a probable reason for freeway ramp and shoulder parking; however, approximately 40% stated differently. In addition, no nearby parking facility being a probable reason was found to be statistically significant during analysis. As for difficulty maneuvering in parking lots, the split between drivers stating it as probable and improbable was quite similar. Specifically, 48% of drivers stated this was a probable reason and 37% drivers stated

[2] Fig. 10 shows the origin of the driver, but may not necessarily be the location that the driver completed the electronic Qualtrics survey.

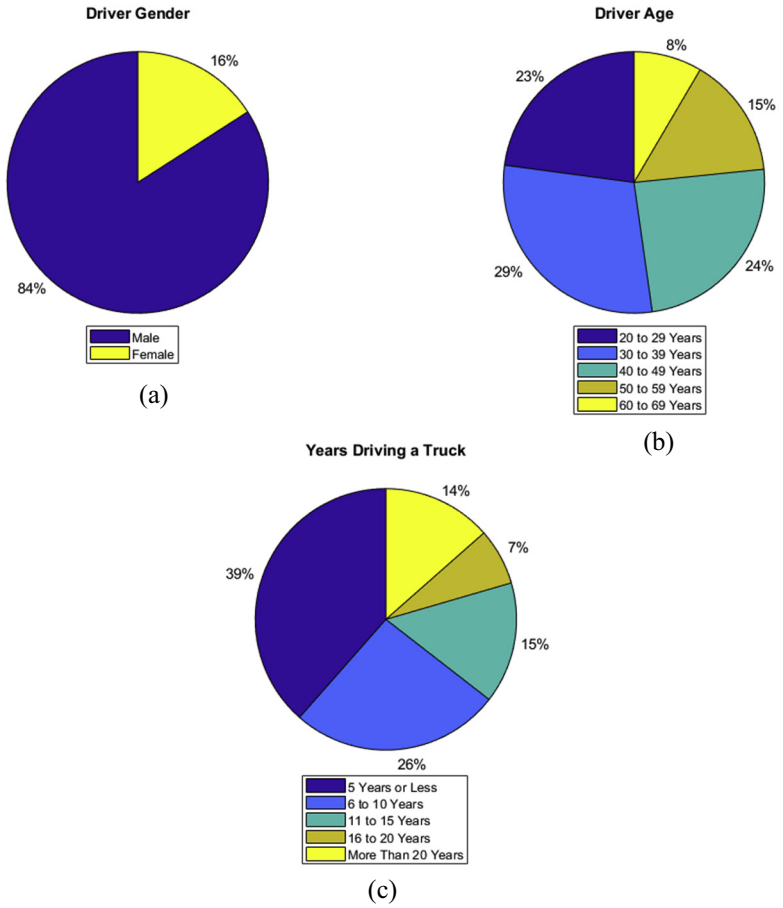

Fig. 1. Driver Characteristics by (a) gender, (b) age, and (c) years driving a truck.

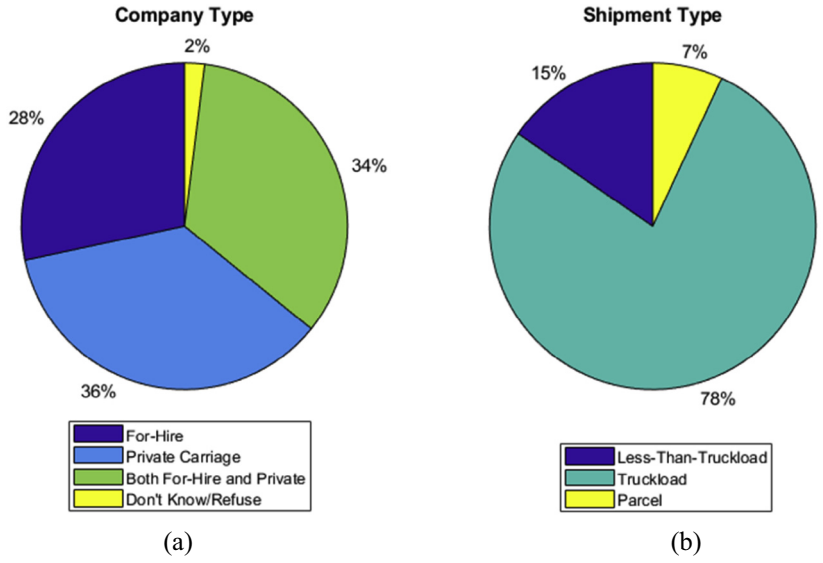

Fig. 2. (a) Company type driver works for and (b) Shipment type.

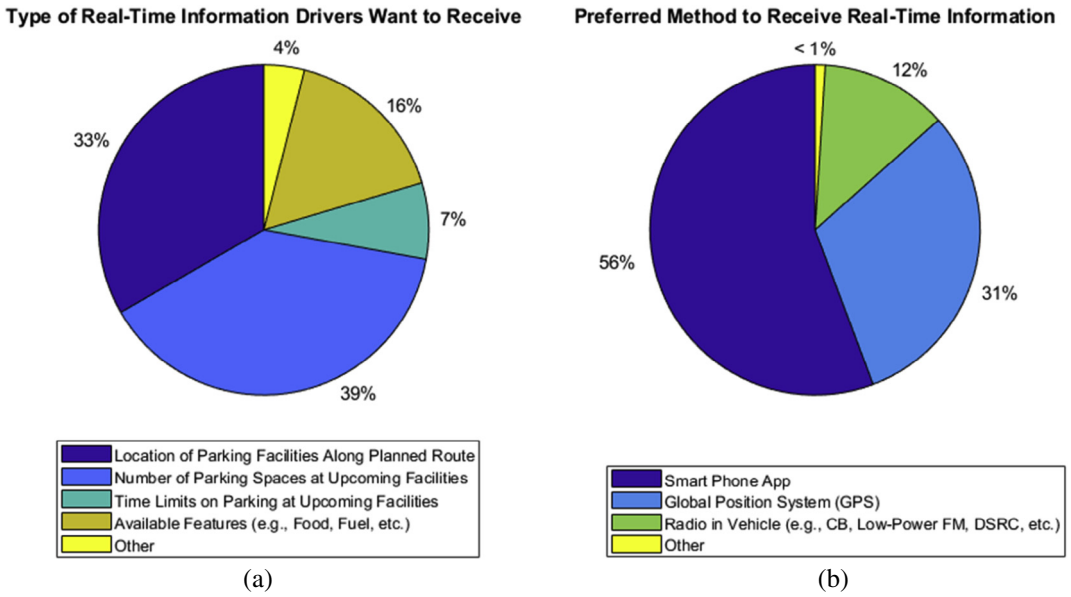

Fig. 3. (a) Type of real-time information surveyed drivers want to receive and (b) preferred method to receive real-time information.

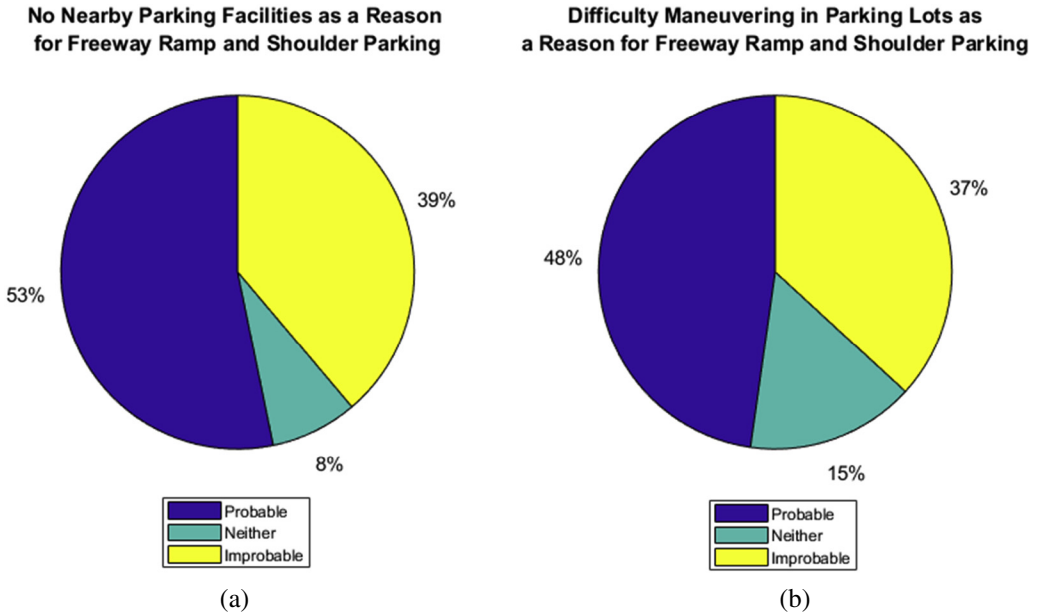

Fig. 4. (a) No nearby parking facilities and (b) difficulty maneuvering in parking lots as probable reasons for freeway ramp and shoulder parking.

this was an improbable reason. More, difficulty maneuvering around parking lots was found to be statistically significant and heterogeneous across drivers during model estimation.

The next set of questions asked drivers to state the importance of specific features at truck parking facilities. Several features were provided to the drivers, but just two were found to be statistically significant, showers and internet connections (shown in Fig. 5). With regard to showers being an important feature when selecting a location to park, more than one-half the surveyed drivers (62%) indicated this is an important feature. Whereas, only 8% and 30% of the surveyed drivers stated showers were unimportant or neither, respecitively. During analysis, drivers that stated showers are important were found to be statistically significant. The second feature that was found to statistically impact perceived safe and adequate parking are internet connections. Although more than one-half of the surveyed drivers stated that an internet connection is important (51%), 19% and 30% of drivers indicated that internet connections are unimportant or neither, respectively. In terms of

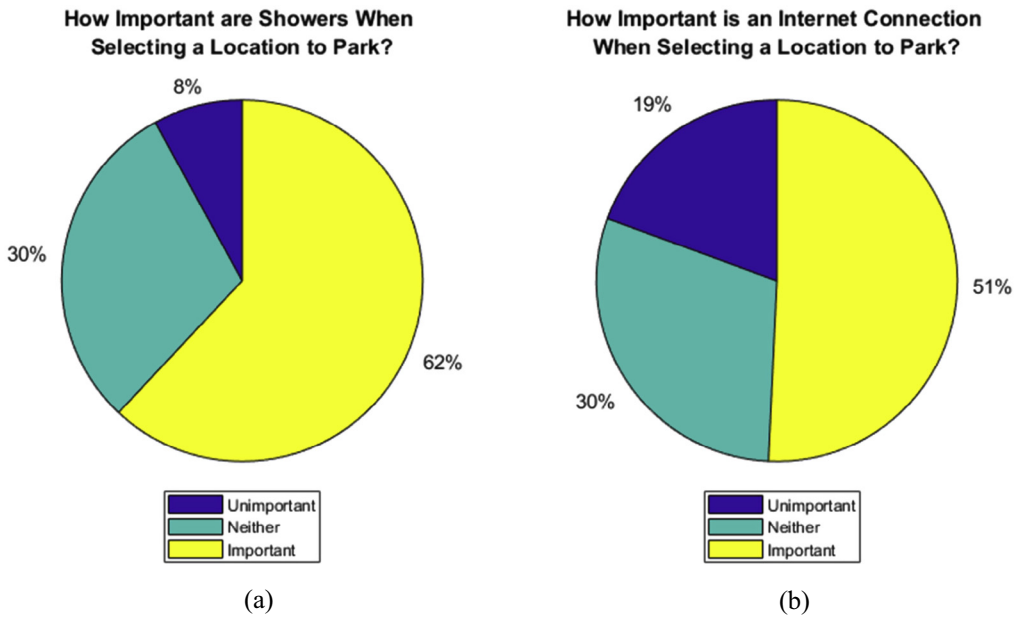

Fig. 5. Importance of features when selecting a location to park: (a) showers and (b) internet connections.

analysis, drivers being indifferent in regards to internet connections (i.e., neither important nor unimportant) were found to statistically impact safe and adequate parking (i.e., designated parking facilties for large trucks).

The final question found to be significant during analysis, as shown in Fig. 6, is related to potential improvements at existing truck parking facilities. Amenity improvement was stated to be effective by 84% of the surveyed drivers, while 13% of the drivers indicated it would be neither effective nor ineffective was an improbable reason. During analysis, drivers that stated no nearby parking facility is a probable reason was found to statistically impact safe and adequate parking from the drivers' perspective. As for difficulty maneuvering in parking lots, the split was similar to that of no nearby parking facility. In terms of a difficulty maneuvering being a probable reason, 48% of the surveyed drivers indicated such; however, 37% of drivers stated this was an improbable reason. In the modeling framework, drivers who stated difficulty maneuvering was an improbable reason was found to be statistically significant and heterogeneous across drivers (see Section 5).

Of particular interest, however, were questions related to issues finding safe and adequate parking. To illustrate, Fig. 7 shows that more than half of the surveyed drivers (61%) encountered issues when finding safe and adequate parking (i.e., designated parking facilities for large trucks).[3] Further, when asked what times of day, week, and year they had troubles finding safe and adequate parking, their responses suggest specific time-periods in which finding safe and adequate parking is more difficult (shown in Fig. 8).[4] As seen in Fig. 8a, drivers have experienced the most difficulty finding safe and adequate during the time-periods of midnight to 5:59 a.m., 4:00 p.m. to 8:59 p.m., and 9:00 p.m. to 11:59 p.m. During analysis, however, no time periods were found to be significant. As for days of the week, Friday was indicated by the surveyed drivers to be most difficult when finding safe and adequate parking (54% of drivers stated such). Monday and Saturday were also selected by a large proportion of drivers to be most difficult when looking for a safe and adequate location park, in which 39% of the surveyed drivers stated Monday is most difficult and 36% stated that Saturday is most difficult. The remaining days of the week (Sunday, Tuesday, Wednesday, and Thursday), were selected by approximately the same proportions of drivers, 26–30%. In the case of analysis, no day of the week was found to be significant; however, an indicator for weekday was found to be significant. The final temporal characteristic drivers were asked to select as most difficult to find safe and adequate parking was month of the year. The winter months of November, December, and January were selected most by drivers at 39%, 57%, and 40%, respectively. In addition, the summer months of June (31% of drivers) and July (38% of drivers) had a large proportion of drivers that stated they have the most difficulty finding safe and adequate parking during these months.

Therefore, to assess the factors that impact safe and adequate parking from a driver's perspective, a total of 134 indicator variables were generated from the driver survey responses and tested for statistical significance through a step-wise procedure; however, just 11 variables were found to be statistically significant. Descriptive statistics for the significant variables

[3] Drivers were asked if they have "ever" encountered problems when finding safe and adequate parking (i.e., it is not time-specific).

[4] For this particular set of questions (i.e., difficult times finding safe and adequate parking), drivers were asked to "select all that apply." As such, the sum of drivers and corresponding percentages will exceed 201 drivers and 100%, respectively.

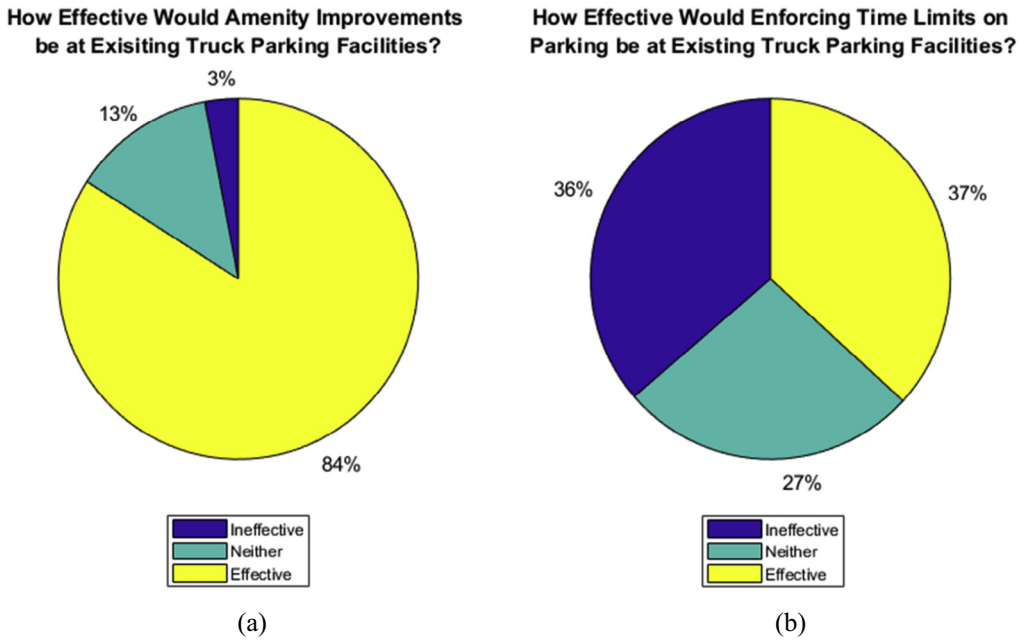

Fig. 6. (a) Effectiveness of amenity improvements at existing truck parking facilities and (b) effectiveness of enforcing time limits on parking at existing truck parking facilities.

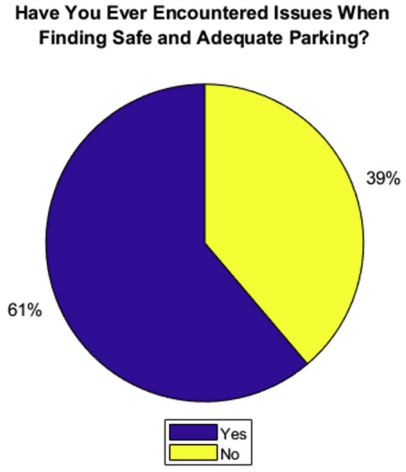

Fig. 7. Percentage of drivers that have encountered issues when finding safe and adequate parking.

are shown in Table 1.[5] In addition, to illustrate the random sample of the survey, the origins of the surveyed drivers are presented in Fig. 10.

4. Modeling framework

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 Dong, 2017; 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 is binary. Accordingly, a binary behavior model is applied.

As previously stated, due to the binary nature of the selected response variable, a binary choice modeling method is applied, binary logistic regression (a binary probit approach is also applicable; however, both models were tested and the

[5] As shown in Table 2, each variable is of at least 90% significance.

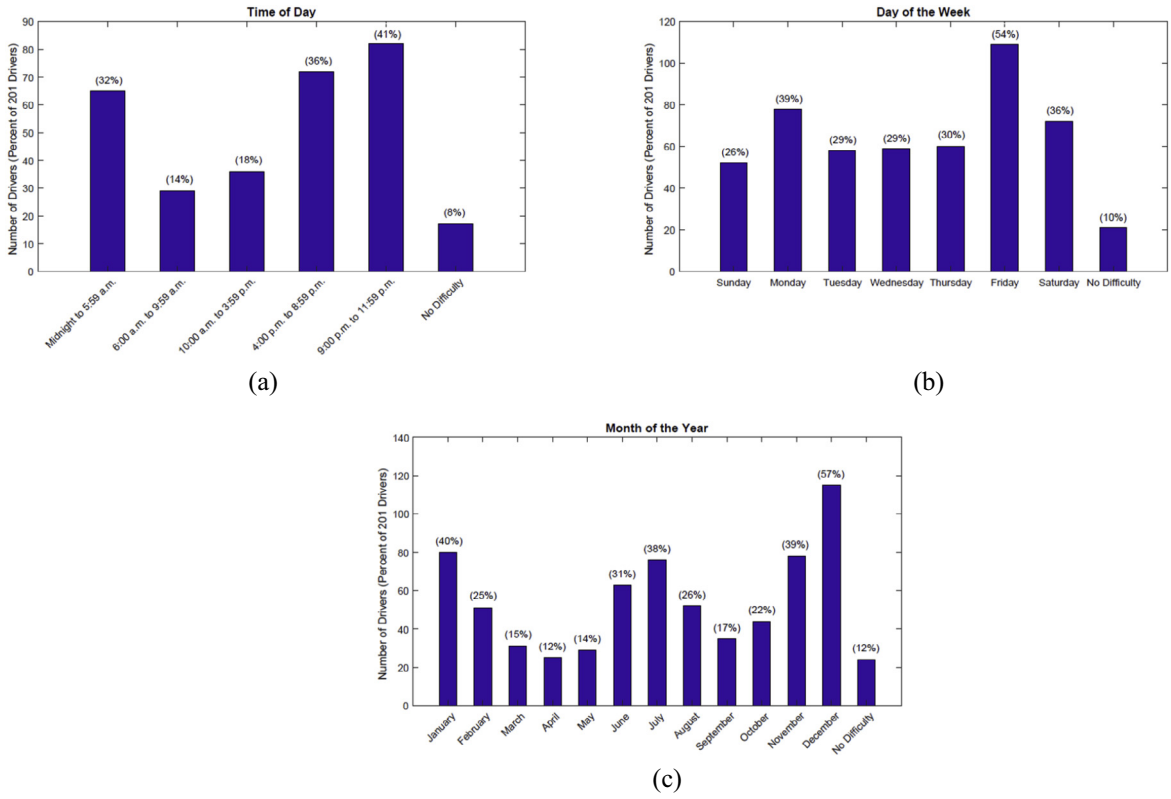

Fig. 8. Difficulty parking by (a) time of day, (b) day of the week, and (c) month.

binary logit model provided a better overall fit). The two possible outcomes are represented by the response variable: 1 if a driver has trouble finding safe and adequate parking, and 0 otherwise (i.e., driver has no issues finding safe and adequate parking). As such, the following binary logit formulation is used to determine the probability that the outcome takes on the value 1 as a function of covariates (Washington et al., 2011):

$$P_n(i) = \frac{e^{(\hat{\beta})}}{1 + e^{(\hat{\beta})}} \quad \text{where } \hat{\beta} = \beta_0 + \beta_1 X_{1,n} + \ldots + \beta_i X_{i,n} \tag{2}$$

where $P_n(i)$ is the probability that a driver of a large truck 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 datasets, heterogeneity (variation) is likely present within the existing variables. For example, driver experience is likely to impact specific factors (e.g., ability to maneuver in a parking facility), but is not captured in the data. Likewise, unobserved factors can impact thoughts on preferred methods of real-time information (e.g., age, experience with types of technology, etc.), yet is also not captured in the data. Most importantly, if this heterogeneity is not accounted for, model estimates and their corresponding inferences can be inaccurate. Accordingly, in an attempt to account for this data heterogeneity by allowing observation-specific variation, a random parameters technique is applied and Eq. (2) is now written as (Washington et al., 2011):

$$P_n(i|\varphi) = \int_X \frac{e^{(\hat{\beta})}}{1 + e^{(\hat{\beta})}} f(\hat{\beta}|\varphi) d\hat{\beta} \tag{3}$$

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). Density function $f(\hat{\beta}|\varphi)$is typically specified to be normally distributed, still several distributions are tested for statistical significance during analysis. For this work,

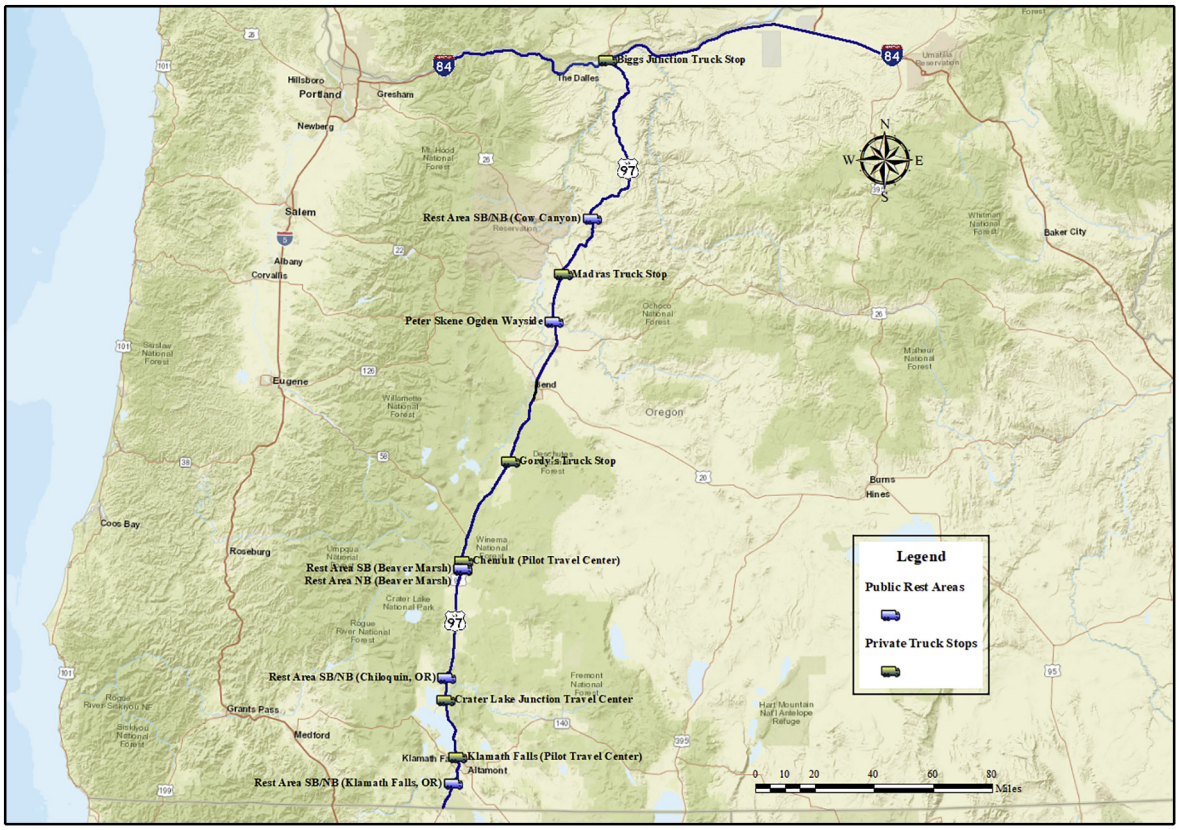

Fig. 9. Private truck stops (green icons) and public rest areas (Blue Icons) on US-97 in oregon.

Table 1
Descriptive statistics of significant variables.

Variable	Mean	Standard Deviation
Response variable		
Trouble finding safe and adequate parking (1 if yes, 0 otherwise)	0.61	0.49
Driver characteristics		
Driver age (1 if between 60 and 69 years, 0 otherwise)	0.08	0.28
Shipment characteristics		
Shipment type (1 if less-than-truckload, 0 otherwise)	0.15	0.36
Temporal characteristics		
Time of week that is most difficult to find safe and adequate parking (1 if weekday, 0 otherwise)	0.08	0.27
Probable/improbable reasons for freeway ramp and shoulder parking		
Probable reason for parking on freeway ramp and shoulder parking (1 if no nearby parking facility is probable reason, 0 otherwise)	0.39	0.49
Improbable reason for parking on freeway ramp and shoulder parking (1 if difficulty maneuvering around parking lots is improbable reason, 0 otherwise)	0.37	0.48
Important features		
Important features when choosing where to park (1 if showers are important, 0 otherwise)	0.08	0.27
Neither important nor unimportant features when choosing where to park (1 if internet connections are neither important nor unimportant, 0 otherwise)	0.30	0.46
Truck parking improvements		
Neither effective nor ineffective truck parking improvements (1 if amenity improvement is neither effective nor ineffective, 0 otherwise)	0.13	0.34
Ineffective truck parking improvements (1 if time limit enforcement is ineffective, 0 otherwise)	0.36	0.48
Real-time information characteristics		
Helpful real-time information (1 if number of available truck parking spaces at upcoming facilities)	0.16	0.37
Preferred method to receive real-time information on truck parking availability (1 if gps, 0 otherwise)	0.31	0.46

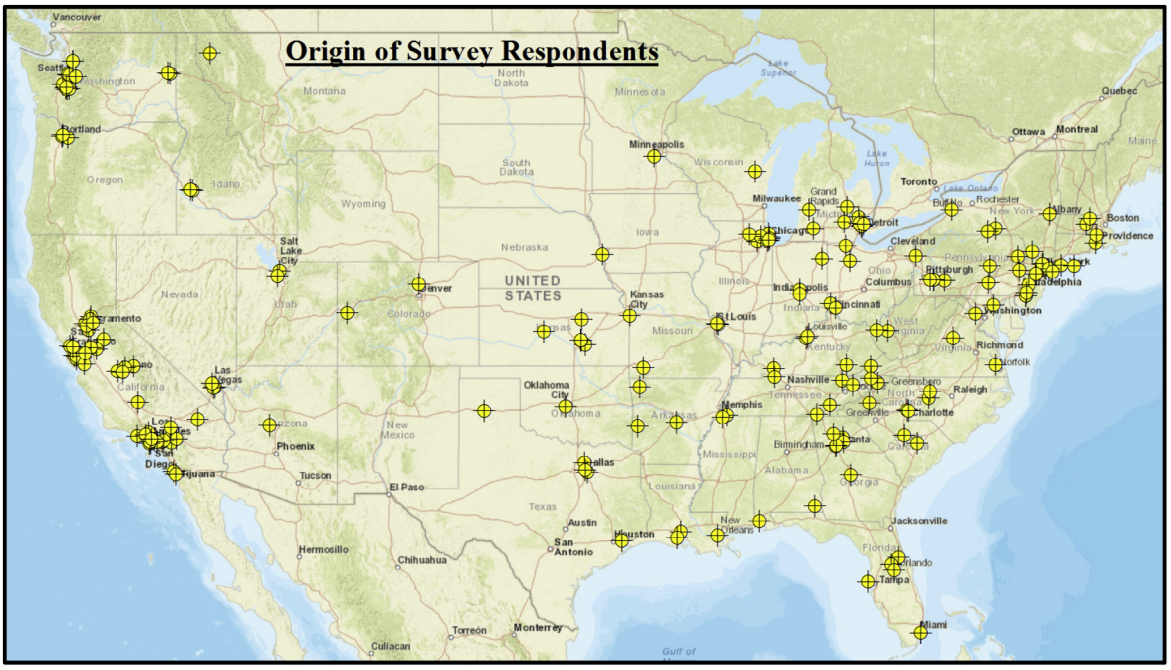

Fig. 10. Origin of drivers of large trucks that deliver goods in the Pacific Northwest.

the normal, uniform, and triangular distributions were tested; yet, only the normal distribution was found to have statistically significant standard deviations.

To assess variable impact, inference from marginal effects are 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 is the difference in probability as indicator variable X_k changes from zero to one while all other variables remain equal to their means (Greene, 2012):

$$ME_{X_k}^{P_n(i)} = \text{Prob}[P_n(i) = 1|X_k = 1] - \text{Prob}[P_n(i) = 1|X_k = 0] \tag{4}$$

5. Model estimation results and discussion

As formerly discussed, a total of 11 variables are 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 2. Of the 11 significant variables, 2 are found to have estimated random parameters (e.g., variation across observations)—the estimated constant ($\hat{\beta}_0$) is also found to be random and normally distributed. To discuss and infer model estimations properly, the discussion will focus on driver, shipment, and temporal characteristics that directly increase or decrease the likelihood of finding safe and adequate parking (i.e., designated parking facilities for large trucks), factors that 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 impact of real-time information on safe and adequate parking from the viewpoint of drivers, will be presented and discussed independently.

5.1. Shipment type, driver, and temporal characteristics affecting safe and adequate parking

Characteristics that directly impact drivers encountering issues with safe and adequate parking include 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 are less likely to perceive problems when finding a safe and adequate location to park. According to marginal effects, drivers with LTL shipments have a 0.32 lower probability of encountering perceived parking issues. This is likely attributed to the length of their haul, as LTL shipments often range between 200 and 600 miles, and drivers are able to make their delivery within the HOS regulations (Stephens, 2017).

Also decreasing the likelihood of encountering issues when looking for a safe and adequate location to park are drivers aged 60–69 years. As with LTL shipments, this age group has a large impact on experiencing perceived parking issues, as marginal effects show that drivers in this age range have a 0.29 lower probability of encountering parking troubles. This

Table 2
Random parameters binary logit model specifications and marginal effects.

Variable	Coefficient	*t*-Statistic		
Constant	1.29	4.67	Marginal effect	*t*-Statistic
(Standard deviation of parameter, normally distributed)	*(0.45)*	*(2.05)*		
Driver characteristics				
Driver age (1 if between 60 and 69 years, 0 otherwise)	−1.30	−1.89	−0.29	−1.95
Shipment Characteristics				
Shipment Type (1 if Less-Than-Truckload, 0 Otherwise)	−1.42	−3.14	−0.32	−3.31
Temporal characteristics				
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
Probable/improbable reasons for freeway ramp and shoulder parking				
Probable reason for parking on freeway ramp and shoulder parking (1 if no nearby parking facility is probable reason, 0 otherwise)	−1.00	−2.93	−0.23	−3.20
Improbable reason for parking on freeway ramp and shoulder parking (1 if difficulty maneuvering around parking lots is improbable reason, 0 otherwise)	−0.62	−1.72	−0.14	−1.76
(Standard deviation of parameter, normally distributed)	*(3.42)*	*(4.72)*		
Important features				
Important features when choosing where to park (1 if showers are important, 0 otherwise)	−1.25	−2.13	−0.28	−2.15
Neither important nor unimportant features when choosing where to park (1 if internet connections are neither important nor unimportant, 0 otherwise)	−0.42	−1.11	−0.09	−1.14
Truck parking improvements				
Neither effective nor ineffective truck parking improvements (1 if amenity improvement is neither effective nor ineffective, 0 otherwise)	−1.23	−2.06	−0.28	−2.08
Ineffective truck parking improvements (1 if time limit enforcement is ineffective, 0 otherwise)	0.84	2.43	0.19	2.30
Real-time information characteristics				
Helpful real-time information (1 if number of available truck parking spaces at upcoming facilities)	−0.93	−2.19	−0.21	−2.29
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)*		
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			

might be explained by the amount of experience drivers in this age group have; that is, safe and adequate parking may be interpreted differently by life-long drivers. It is possible that any open space, whether it is a dedicated parking location or not, is considered safe and adequate for these drivers. For example, if a driver has been parking on freeway shoulders or on/off ramps over a substantial period of time with no troubles, they may perceive it as a safe and adequate place to park.

As for the time of the week, having trouble finding safe and adequate parking on a weekday is more likely. Marginal effects suggest a 0.50 higher probability of perceiving there to be issues when 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 is more difficult on weekdays. This result is intuitive, being that the largest total traffic volumes and large truck volumes are seen during these days. When the demand for parking is higher due to larger traffic volumes, there is an inherent shortage of safe and adequate parking. Although there have been works to address delivery of goods during non-peak hours, it is still an ongoing process to mitigate large truck volumes during peak volume hours.

5.2. Facility characteristics leading to unsafe and inadequate parking

To gain a better understanding with regard to parking on freeway ramps and shoulders, and its effect on having troubles finding safe and adequate parking, drivers were asked what probable (or improbable) reasons would lead to parking in these locations. For example, if no nearby parking facilities is a probable reason for parking on freeway ramps and shoulders, drivers believe they are less likely to encounter problems when looking for safe and adequate parking. In other words, if there is no nearby parking facility, drivers may decide to park in a location they deem safe and adequate. If this is the case, these drivers will not report that they experience parking issues on account of them believing they are parking in a safe and adequate location. In fact, marginal effects show that drivers who think no nearby parking facilities being present is a probable reason for parking on freeway ramps and shoulders have a 0.23 lower probability of perceiving issues when finding a safe and adequate location to park—again, this is likely due to drivers genuinely believing that where they are parking (e.g., freeway ramps and shoulders) is a safe and adequate location. Parking in these locations has also been found to decrease designated truck parking facility utilization (Haque et al., 2016).

Referring to the next significant factor, difficulty maneuvering in parking lots being an improbable reason for parking on freeway ramps and shoulders, the estimated parameter ($\hat{\beta}$) was found to be random and normally distributed based on 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 is greater than zero for 42.8% of drivers and less than zero for 57.2% of drivers.

That is to say, 42.8% of drivers believe difficultly maneuvering around parking lots leads to perceiving problems when finding safe and adequate parking, yet 57.2% of drivers believe differently. The non-homogenous nature seen here may be a result of driver experience or size of the truck. For instance, if a proportion of drivers have a significant amount of experience, they are likely to have minimal issues when maneuvering their truck in terms of parking (e.g., a driver that has driven the same truck for many years), while some drivers operate a truck that is simply too big to maneuver safely in certain parking locations.

5.3. Important features impacting safe and adequate parking

Two features are found to be statistically significant in determining the likelihood of a driver perceiving problems when looking for safe and adequate parking, according to the surveyed drivers. The first feature, showers, is an important feature to drivers and decreases the likelihood of them perceiving issues when trying to find a safe and adequate area to park, and marginal effects show a 0.28 lower probability of such. 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 safe and adequately. More, the presence of showers may indicate newer facilities with a larger number of available spaces; hence, issues finding perceived safe and adequate parking are decreased. 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% of the surveyed drivers indicated that showers were an important feature, therefore the percentage of drivers that think such is presumably low.

The second feature, internet connections, is neither important nor unimportant to drivers and marginal effects indicate a 0.09 lower probability of perceiving troubles when finding safe and adequate parking. In this case, considering internet connections are neither important nor unimportant, drivers are likely to park at the nearest location with available spaces; therefore, encountering parking issues is less likely. This may be attributed to the widespread use of mobile phones with unlimited data plans and, as a result, there is no serious need for internet connections.

5.4. Effectiveness of potential improvements on safe and adequate parking

To shed light on the effectiveness of potential truck parking improvements from a driver's point of view, two potential improvements are found to statistically impact 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 is significant and decreases the likelihood of experiencing parking issues. This finding might be linked to drivers believing that current amenities are fine and that an improvement would not affect their parking decision, therefore experiencing parking issues is less likely. Further, marginal effects show a 0.28 lower probability of perceiving to have problems when looking for a parking location if a driver believes amenity improvements are neither effective nor ineffective.

The following potential improvement, time limit enforcement being ineffective, is found to increase the likelihood of perceiving problems finding parking and marginal effects indicate a 0.19 higher probability of such. A possible explanation could be that drivers prefer to park and rest on their own time schedule and not be forced to leave before they are rested. This would be especially true if drivers choose to park at a location where the time limit is less than the required rest time to meet HOS regulations, but the chosen location is the only safe and adequate parking location for several miles (i.e., designated parking facility for miles). This result suggests that rather than enforcing time limits, extend them to meet the 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. Effect of real-time information on safe and adequate truck parking

With regard to real-time information and the impact it has on finding safe and adequate parking according to drivers, information about the number of available truck parking spaces at upcoming facilities and GPS being the preferred method to receive real-time information are statistically significant. Real-time information on the number of available truck parking spaces at upcoming facilities decreases the likelihood of drivers perceiving parking troubles and marginal effects show a 0.21 lower probability of encountering troubles. This result is fairly intuitive, as drivers can prepare for parking while driving. As such, drivers likely believe they are 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 that are past their HOS threshold being on the highway, likely fatigued, searching for an adequate place to park.

Turning to the preferred method to receive real-time information about truck parking availability, according to drivers, GPS is found to be statistically significant. Further, the estimated parameter for GPS being the preferred method to receive real-time information is random and normally distributed. A mean of 1.21 and a standard deviation of 2.65 imply that the estimated parameter mean for GPS is less than zero for 32.4% of drivers and greater than zero for 67.6% of drivers. In other words, 32.4% of drivers believe encountering troubles when looking for a safe and adequate place to park is less likely, while 67.6% of drivers believe it is more likely. The heterogeneous effects seen here may be a result of not all drivers believing GPS is the preferred method for receiving real-time parking information. For instance, roughly one-half of the surveyed drivers are younger than 40 years of age and the randomness in this estimated parameter may be accounting for drivers that believe

a more useful way to have real-time information disseminated is through a smart phone application. On the other hand, older drivers may prefer 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, there is still a percentage of drivers that would not benefit from real-time information being provided by GPS.

6. Summary and concluding remarks

The current study utilized a survey issued to drivers of large trucks that 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 the drivers. Due to data heterogeneity, a random parameters binary logit approach was applied to produce the most accurate estimates and to infer appropriately. With that in mind, heterogeneity within two variables was found; particularly, within 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 impact safe and adequate parking. These factors include LTL shipments, drivers between the ages 60–69, and weekdays. Other than weekdays, these factors are less likely to result in troubles finding safe and adequate parking, therefore suggesting that future truck parking studies should put a focus on truckload shipments and younger age groups. In the context of the remaining significant factors that lead to drivers believing (or not believing) that they will experience issues when looking for a safe and adequate place to park, there is subjectivity present and needs to be mitigated in future truck parking efforts. 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. On account of this, such subjectivity needs to be properly accounted for in future works. 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 what would be the most beneficial method to deliver the information.

In summary, the current study has provided an empirical method to determine factors associated with safe and adequate truck parking troubles. This method allows the analyst to identify key factors based on 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 amount lives by mitigating the related safety concerns for all users of the Nation's highway infrastructure.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ijtst.2018.01.001.

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