OREGON COMMERCIAL TRUCK PARKING STUDY

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Subject: Methodology and Data Assessment Technical Memorandum

1. INTRODUCTION

One of the main analyses of the Oregon Commercial Truck Parking Study will be the estimation of truck parking demand along the study corridors (see Figure 1). This estimate will be compared against existing truck parking capacity to identify shortfalls and inform proposed investments that would improve truck operations in the state. However, this is not a simple task because no single data set exists that provides a complete picture of where trucks are parking.

To better understand the state of practice in truck parking studies, the study team prepared a Literature Review (Technical Memorandum #1). The review focuses on methods and approaches of previous studies. It included eleven state and local truck parking studies from around the country, several federal studies (including the guidance coming from the National Coalition on Truck Parking) and sixteen recent research studies. The Literature Review included a summary of lessons learned pertinent to each task.

This Technical Memorandum describes an approach for estimating total parking demand while attempting to overcome the challenges and limitations of other studies. The approach builds on lessons learned in previous studies and develops innovative ways of leveraging the data available in Oregon. Section 2 of this Memorandum presents a summary of the previous approaches that have been used in the literature and provides an overview of the approach proposed for this study, which consists of three steps that are described in greater detail in Sections 3 through 5.

Truck drivers stop for a variety of reasons. They take a mix of 30-minute breaks and 10-hour (typically overnight) stays in order to meet the federal Hours-of-Service (HOS) regulations (described in the Literature Review Memorandum). However, some need to spend additional time parked waiting for a scheduled delivery or pickup, and even waiting for their next load. Short-haul trucks have different parking needs than long-haul trucks, and refrigerated trucks might need to stop more frequently. This variety of needs makes it challenging to estimate total parking demand throughout the system.

The demand for truck parking also varies spatially and temporally. Understanding these patterns is critical to isolate the roads with persistent or occasional truck parking issues, and develop solutions that address the specific issues. Parking demand typically varies in the following way:

- **Hourly Variability:** Demand for truck parking follows a distinct pattern throughout typical weekdays, with space availability peaking at around 2-4pm, and then decreasing progressively throughout the afternoon and into the night, until for some lots all spaces are taken up. Generally, availability is at its lowest at around 4am in the morning.
- **Daily Variability:** Not only does demand fluctuate between weekdays and weekends, it also fluctuates Monday through Friday. For example, previous studies have found that Wednesdays and Thursdays have significantly higher parking demand than other weekdays.
- **Seasonal Variability:** Freight demand spikes during certain times of the year, such as in the lead-up to the holiday season. The greater volume of trucks on the roads will necessarily increase parking needs.
- **Random Variability:** Even if the variability described above is accounted for, parking demand could fluctuate significantly between two days with seemingly identical conditions. A component of parking demand is random in nature. This implies that enough evidence or data is needed to estimate truck parking demand from observational data, to average out the random variations.

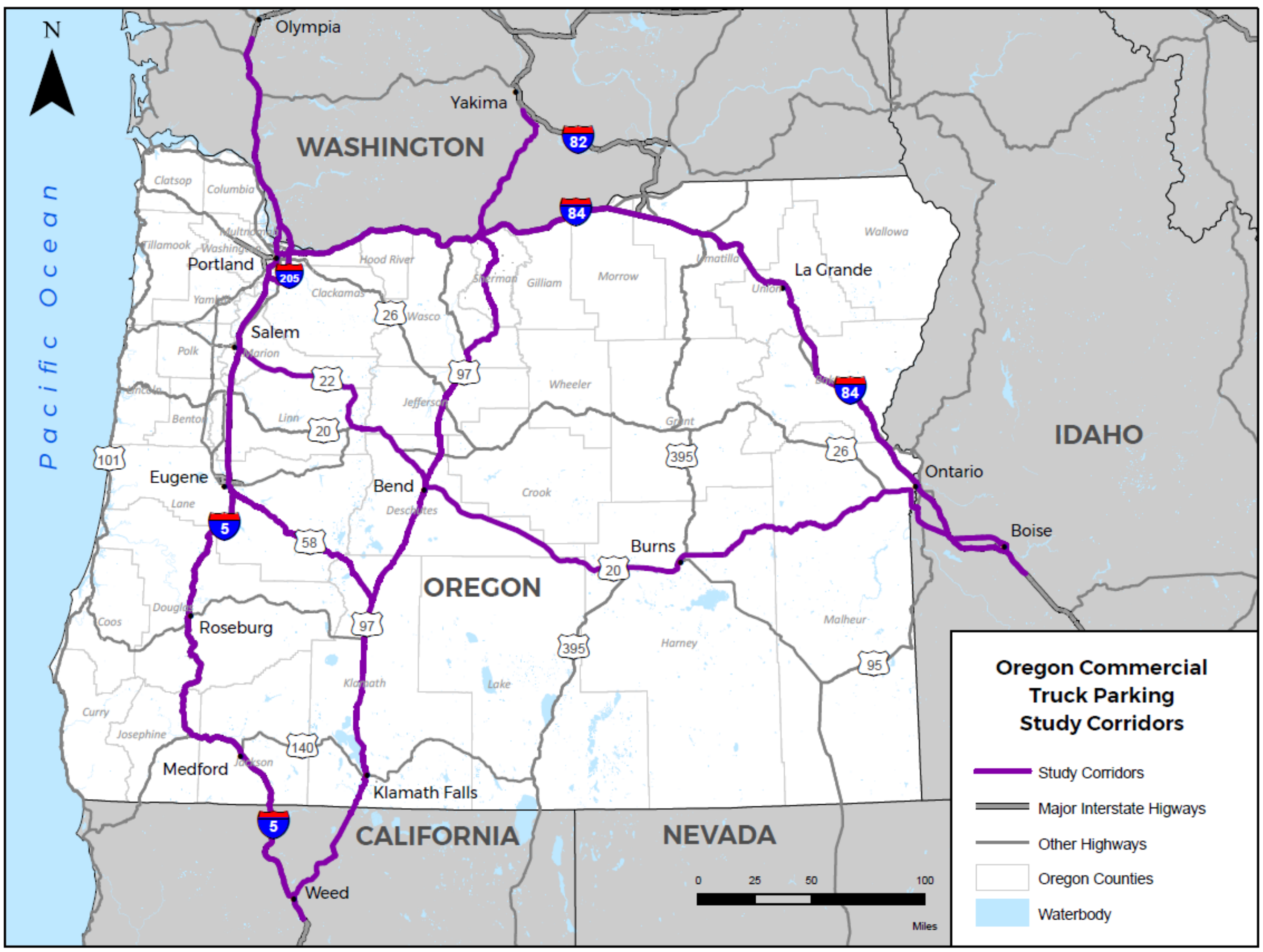
Estimating parking demand is made more challenging by the fact that trucks park in different types of locations. Generically, these can be described as formal or designated and undesignated but there is some grey area in these definitions. For clarity, this study breaks down designated and undesignated parking into more specific types, as follows:

- **Rest Areas:** Publicly operated parking facilities that serve both passenger vehicles and trucks. They typically offer few amenities (regulators forbid providing commercialized services at these facilities). There are 32 rest areas managed by TIC along the corridors being studied.
- **Commercial Truck Stops:** Privately owned and operated parking facilities, some of which cater specifically to truckers. These facilities typically offer many more amenities than rest areas.
- **Commercial Establishments:** Privately owned parking lots that serve retail establishments where overnight truck parking is permitted (such as some Walmarts).
- **Undesignated Sites:** Locations along the right-of-way, or in nearby parking lots where truck parking is technically not allowed.
- **Truck Terminals:** Truck lines in some for-hire market segments (e.g. LTL, small package, tank trucking) maintain terminals that also function as driver domiciles. Terminals are not everywhere and drivers do make use of rest areas and other facilities, but they have in-house options serving many of their needs. Similarly, private fleets (e.g. Sysco, Coca-Cola) typically base their drivers at company facilities such as plants and distribution centers.

Despite these challenges, developing a reliable estimate of truck parking demand is fundamental to ensure that the State implements strategies that address the parking issues faced by trucks as they operate throughout Oregon. Ideally, the demand estimate would consider parking at all these locations, and for any reason. Most previous studies have only considered a subset of parking demand, by focusing only on some of the reasons for parking (such as HOS regulations) or using facility data from a limited number of rest areas or truck stops. While this could provide a partial picture of truck parking trends in the state, it doesn't provide a complete estimate of the shortfall along corridors.

The approach detailed in the next sections, attempts to be as inclusive as possible, within study budget. Truck Terminals will not be analyzed in detail, as they are self-contained. However, truck terminal locations that are identified will be noted in order to provide a more complete picture.

Figure 1: Study Corridors



2. Methodology Assessment

2.1 Previous Approaches

The Literature Review Memorandum describes the many approaches that have been used in the past to estimate truck parking demand. These approaches can be roughly categorized into the four types shown in Table 1. The most popular approach has been to use the Federal Highway Administration's truck parking demand formulas first published in 2002.[1] These formulas describe the hours of truck parking demanded along a corridor as a function of truck volumes and other factors. However, as indicated in the table, this approach has several weaknesses that lead to biased estimates. The main limitation is the reliance on previously estimated parameters that are typically not validated with local data. In addition, the HOS regulations have changed since 2002; for example, the standard work shift lengthened from ten to eleven hours.

Another approach, which has been implemented in Arizona, uses data from a truck parking application to describe truck parking demand. This type of data could be helpful to identify those parking facilities that are full more often, however it also has limitations as described in the table. Foremost, data from truck parking applications does not adequately capture parking at undesignated locations. This represents a significant blind-spot, particularly in high volume corridors where parking lots are often full.

Table 1: Main Approaches Used to Estimate Demand in Previous Studies[2]

Approaches	Previous Uses	Strengths	Weaknesses
2002 FHWA Demand Formula: analytical model to predict parking demand on a corridor segment as a function of the proportion of truck traffic, the annual total traffic, the length of the segment, the average speed of trucks, and the average parking time per travel time.	US-97 (Oregon), Virginia, Utah, Atlanta	Simple to implement. Inputs are readily available. Provides high-level estimate. In theory, estimates total parking demand.	The main weakness of this model is the use of parameters that represent average parking time per drive time, which were estimated over 15 years ago and are not likely to be representative of local conditions. Additionally, daily demand fluctuations are accounted for through generic peaking factors that are also not representative of local conditions. Finally, the estimation parameters focus on the effect of hours-of-service regulations, and ignore other reasons for parking.
Facility Availability from Trucker Path Application:	Arizona	Provides detailed description of availability	Ignores parking in undesignated locations. Crowdsourced reports from

[1] FHWA (2002) Model Development for National Assessment of Commercial Vehicle Parking
[2] This covers only the demand estimation approaches and does not include all data sources. Data sources are covered in more detail in the next section.

Analysis of Trucker Path data showing whether facilities were reported as "full", "some spots available", "lots of spots available".		at some facilities, throughout the day and throughout the year.	drivers might be infrequent, inaccurate, or withhold locations drivers wish not to be widely known. Availability categories are very coarse and subjective. Proprietary access.
Analysis of GPS Records: Counts number of parking stops within the boundaries of public facilities. Sometimes undesignated parking is quantified as well.	Arizona, Kansas, Atlanta	Can consider parking at designated and undesignated locations, for any reason. Provides time of day and day of the year detail. Can track ultimate origin or destination of trips.	Only a subset of all trucks are included in GPS database. Does not estimate total demand. Parking at loading/unloading facilities needs to be excluded.
Analysis of Expanded GPS Records: Expansion factors are calculated using observed counts to estimate the number of real-life trucks that each GPS truck represents. Total demand is estimated as described above.	Minnesota, Diaz-Corro et al. (2018)	Can potentially provide the most comprehensive demand estimate, considering total designated and undesignated.	Ground-level observations required, preferably that coincide with the GPS database.

Several studies have tried to quantify truck parking demand using GPS data. This approach has the advantage of considering truck parking in both designated and undesignated locations, for any reason. It also has the ability to provide great detail on parking patterns, throughout the day and throughout the year, in addition to describing parking along specific corridors or regions. The main disadvantage with this approach is that it only considers trucks instrumented with GPS recorders, which could be a fraction of all trucks on the road.

Lastly, the latest research in truck parking demand has focused on developing expansion factors for the GPS data that indicate the proportion of truck activity represented by each GPS record. The main challenge in this approach has been that ground-level observations are needed to develop the expansion factors. Often, the observed data is not precise enough to be compared directly to the GPS data, as occurred in Diaz-Corro et al. (2018).

2.2 Information Sources

2.2.1 Data

Below is a list of sources of information that are available in Oregon or could be acquired. Note that not all of these will be used in the estimation of parking demand.

- **GPS Data:** There are several vendors of truck GPS data. The American Transportation Research Institute (ATRI) maintains the largest database, tracking approximate 800,000 trucks that operate nationwide. INRIX and other commercial vendors also track trucks and develop their own databases, however they are less transparent about the number of trucks included and their characteristics.
- **Ground-level Observations:** Some previous studies have relied on site surveys to estimate the demand at truck parking facilities. More sophisticated attempts have

involved taking video of the truck parking facilities and recording demand levels throughout the day. Because of the costs involved, it is common for these efforts to be limited in scope and duration.

- **Smartphone and Web Applications:** Several applications have been developed to help truck drivers find parking spaces. Two of the more popular ones are Park My Truck and Trucker Path. Park My Truck is an application that provides information about the location and amenities of selected truck stops, and for some of them includes information about the availability of parking spaces. This application only covers a subset of all the facilities. Trucker Path crowdsources parking availability information by asking truck drivers whether facilities are "full", or have "some spaces" or "lots of spaces". This data has been used in previous studies to describe truck parking demand, however, there are several limitations with relying solely on this information. As described previously, not only are the availability categories too coarse to quantify needs, but different drivers are likely to have different definitions of "some" and "lots". The reporting frequency is also too low at certain facilities to characterize demand fluctuations throughout the day.
- **Law Enforcement Records:** Citations for undesignated parking could provide valuable information on where such parking is taking place. This data has been used successfully in previous studies, however, it provides a partial picture, so would need to be used in combination with other data. If desired, we could explore how citations of this kind are handled in Oregon and inquire about obtaining this data.
- **EROAD:** This company developed in-cab technology for displaying information to drivers with the objective of improving efficiency and safety. This technology also tracks trucks, creating a log of their speeds and where they stop, among other characteristics of the trips. We do not believe this data is critical for this study because it provides some of the same location information available in ATRI's GPS database. Moreover, to our knowledge, ATRI's database is the most expansive truck location database available in the U.S.
- **FleetSeek:** This is a database of trucking operations and contacts. Users can access detailed information about the trucking sector, including demographics, contact information, and fleet information. We do not believe that this database would be useful to estimate truck parking demand because, based on a review of their website, it does not appear to provide stop location information.
- **Transearch:** This is a proprietary nationwide commodity flow database that describes shipments by commodity, mode, geography, industry, etc. The flows can be routed on the roadway network. Detailed in terms of volumes, the information provided by this database is most useful as a segmentation tool, allowing distinction between traffic types with different categories of need. Some of the key categories Transearch identifies are private trucking, LTL, tank and temperature controlled trucking, and general separation of the traffic mix by length of haul. However, because they are the output of an assignment model that makes assumptions about the operations of the sector, the truck volume estimates from Transearch are less accurate than the truck volume information already available from ODOT (truck AADT).

2.2.2 Results of Outreach

Twenty five interviews will be conducted as part of this project. These interviews will include questions to identify the corridors or segments that have high levels of truck parking demand. Questions will also be included to identify the locations of undesignated truck parking. A survey with similar questions will also be distributed broadly. The following groups of stakeholders will be interviewed and surveyed:

- Oregon DOT HQ Staff
- Oregon DOT District Staff
- Local Government Staff
- Truck Drivers and Fleet Managers
- Oregon State Police (OSP)
- Private Truck Stops
- Oregon Travel Information Council (TIC)

The survey will include a mapping exercise where respondents will be able to identify places along the corridor that face specific truck parking problems. The results will be available for the demand and needs estimation.

2.3 Overview of Proposed Approach

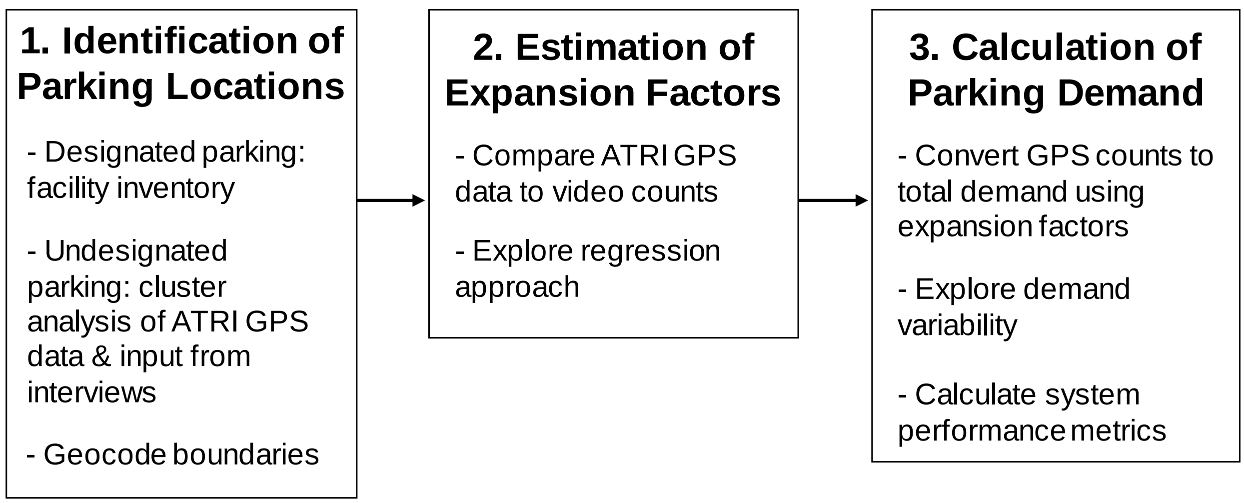
The approach proposed to estimate truck parking demand is outlined in Figure 2. First, the locations where trucks are parking will be identified and geocoded in GIS. Designated parking locations will be obtained from the facility inventory that is being developed in another task of this project. Geocoding the off-ramps and on-ramps to these facilities is important as trucks tend to park at these locations when lots are full.

For undesignated parking, ATRI's GPS data will be analyzed to identify clusters of parking along the project corridors that appear to represent undesignated truck parking. These locations will be geocoded as well. A set of ATRI GPS data covering 16 weeks in the past year (4 weeks per quarter) for all trucks traveling less than 25 mph in Oregon (within a 10-mile buffer of the state's boundary). An algorithm will be developed to process this data to identify stopped trucks.

The next step involves the estimation of expansion factors, by comparing the ATRI GPS data to video evidence at certain parking facilities. Six rest stops will be recorded for 24 hours and four rest stops will be recorded for 48 hours. These videos will be processed, noting how parking utilization fluctuates throughout the day. As described later in this memo, a regression approach will be explored for calculating the expansion factors. It is likely that this approach will generate better results than the simple comparison of averages used in previous studies. If it doesn't produce better results, then we will revert to using the previous approach.

Finally, total parking demand along the corridors will be calculated by counting the GPS records in the designated and undesignated parking locations, using the expansion factors to estimate how many trucks are represented in real-life. Variability in demand will be described throughout the day, week, and year. The analysis will focus first on overnight parking, although shorter rest periods will be captured as well and will be analyzed to the degree possible within study resources. Random variations in demand will also be characterized. A variety of system performance metrics will be calculated based on this demand analysis. Details for all these steps are provided in the following section.

Figure 2: Overview Truck Parking Demand Estimation



3. IDENTIFICATION OF PARKING LOCATIONS (STEP 1)

The first step of the analysis will be to identify the locations where trucks are parking. This would then allow us to count the number of GPS parking events within the boundaries of these facilities. Parking locations will be identified through the following:

3.1 Rest Areas and Commercial Truck Stops

These facilities will be identified using the facility inventory that is being developed by another task of this project. A GIS file will be created that delineates the boundaries of the area where trucks are able to park. The amenities and services available at these locations will also be noted.

3.2 On/off Ramps to Rest Areas

Many previous studies have found that trucks often tend to park on the shoulders of the on-ramps or off-ramps leading to parking facilities. In some cases, parking on these shoulders is prevalent even when the facilities have availability. Given this, the on/off ramps will also be delineated with a boundary file in GIS so that demand can also be quantified at these locations.

3.3 Commercial Establishments

Trucks park overnight at the parking lots of some commercial establishments, such as Home Deport or Walmart. Some of these commercial retailers have policies that allow overnight truck parking. This type of parking will be identified by finding clusters (in the GPS data) of truck stopped overnight around commercial establishments. Trucks stopped for shorter periods will be excluded to eliminate trucks that make deliveries throughout the day. Research will be conducted to identify major locations of this nature and rules that govern their use. Some parking applications, such as Trucker Path, provide information on commercial establishments that allow parking.

3.4 Undesignated Sites

Undesignated parking can occur at:

- Shoulders
- Interchanges
- Pullouts
- Chain-up areas
- Vista points
- On/off ramps

Parking in undesignated areas is typically difficult to identify because these locations are not listed anywhere and their popularity tends to change over time.

The primary way that undesignated parking will be identified will be through interviews and surveys of local agency staff. There are numerous places that are known for having this issue throughout the study corridors. In addition to this, we will manually scan ATRI's GPS data of the corridors in Oregon to identify other undesignated places that see substantial numbers of trucks routinely parking overnight. The boundaries of these sites will then be geocoded in GIS.

4. ESTIMATION OF EXPANSION FACTORS (STEP 2)

Expansion factors will be calculated that quantify the number of actual trucks that each GPS record represents. ATRI's truck GPS database is extensive, encompassing 10 to 40 percent of all trucks operating on any given corridor, however we are interested in estimating the parking demand for all trucks, not just trucks that are instrumented by GPS devices. To calculate the expansion factors, we will compare the counts obtained from the video recordings to the GPS parking counts during those exact same time periods.

Estimating truck parking demand by expanding GPS data has been attempted twice before, by ATRI in Minnesota[3] and university researchers in Arkansas[4]. However, both of these studies had limitations that restricted their ability to precisely calculate the expansion factors. In the ATRI study, the expansion factors were calculated comparing mainline traffic volumes to GPS volumes, and not directly on trucks parking activity. In the Arkansas study, GPS records could only be compared to the average parking occupancy during night time hours, because observation data came from a site survey that did not indicate precisely when the measurements were recorded. The approach described below avoids these limitations by calculating the expansion factors directly on truck parking activity, and using video data that can be compared directly to the GPS data.

4.1 Comparison of Averages

At a basic level, the expansion factor E for a particular parking facility (or group of parking facilities) can be calculated through

$$E = \frac{N}{R} \qquad (1)$$

where N is the average number of trucks observed parked (from the videos in our case) and R is the average number of GPS records of trucks parked. Given that our data include time resolution $t = 1,2, \dots ,T$, where T is the number of time periods in the day, the average expansion factor throughout the day can be calculated as

$$E = \sum_{j=1}^{J}\sum_{t=1}^{T}\frac{N_t}{R_t}N_t \Bigg/ \sum_{j=1}^{J}\sum_{t=1}^{T}N_t \qquad (2)$$

where $j = 1,2, \dots ,J$ is an index of parking facilities, N_t is the number of parked trucks observed at t, and R_t is the number of GPS records showing parked trucks at t. This equation calculates the expansion factor for each facility for each time period, and then averages these values over all the facilities and time periods, weighting the values by the number of observations. In other words, the aggregate expansion factor is calculated as the weighted average of expansion factors at each facility for each time of the day. Combinations of j and t without data for both N_t and R_t can be ignored.

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[3] ATRI (2015) Managing Critical Truck Parking Tech Memo #2: Minnesota Case Study

[4] Diaz-Corro, K. et al. (2019) Comparison of overnight truck parking counts on GPS derived counts for truck parking facility utilization analysis, Proceedings of the Transportation Research Board Conference, Washington, DC.

4.2 Regression Model

The approach described in the previous section follows the literature in calculating the expansion factors directly from the data. Depending on the density of the GPS data (how many instrumented trucks park overnight), it might be possible to estimate the expansion factors more robustly through a regression model. This model could have the general structure

$$N_i = \alpha R_i + \boldsymbol{\beta} \boldsymbol{X}_i + \varepsilon \qquad (3)$$

where i represents distinct observations (different time periods and different facilities), N_i is the ground-level observation of truck parking, R_i is the number of GPS records parking, α is the parameter estimate for the number of GPS records, $\mathbf{X}_i$ is a vector of covariates that can explain differences between observed counts and GPS records, $\boldsymbol{\beta}$ is a vector of parameter estimates, and ε is the error term of the model. In this approach, the parameter estimate α represents the average expansion factor in the dataset, controlling for other variables $\mathbf{X}_i$ that might be causing GPS records to deviate from observations.

Estimating the expansion factors this way has the advantage that other variables can be considered to explain truck parking demand in addition to GPS records, which will lead the model to produce better demand estimates. Some of the covariates that could be considered include: truck volumes (short-haul vs. long-haul) on the mainline road, time of day, day of the week, specific corridors, type of parking facility (private vs. public vs. undesignated), etc. Different variables could be considered to explore whether their inclusion improves the estimates. This approach recognizes that the objective of the analysis is not to generate expansion factors per se, but instead to develop a model that predicts truck parking demand as a function of available data (given that observed data is not available everywhere). The more variables are included in the model, the more data will be needed to estimate significant parameters (if they are significant). This represents a tradeoff that will be explored once the models are estimated.

Different model structures will also be explored, such as multiplicative structure instead of an additive structure. Ultimately the type of model that can be estimated depends on the amount and quality of the data available. It is difficult to distill patterns if too much noise is present in the data. Whether this is the case can only be known once the data is analyzed.

As was done by FHWA (2002), parking demand can be estimated in terms of vehicle hours of parking (VHP) per vehicle hours of travel (VHT). In that previous study, this ratio was calculated based on the typical rest hours of truck drivers relative to the hours of driving. This value was assumed based on the HOS regulations, and was not calculated from observational data. ATRI's GPS database can potentially offer a more precise way of estimating this ratio. The network can be discretized into 100 mile segments, and from this data it is possible to estimate the vehicle hours of parking in the GPS data for segment s in time period t as VHP_{st}. This data can also be used to estimate the vehicle hours of travel in the GPS data on the mainline segment as VHT_{st}. The relationship between VHP_{st} and VHT_{st} can be explored with the following model

$$VHP_{st} = \rho VHT_{st} + \boldsymbol{\beta X}_{st} + \varepsilon \qquad (4)$$

where ρ represents the average vehicle hours of parking per vehicle hours of travel, and $\mathbf{X}_{st}$ is a vector of covariates that might help explain other factors that contribute towards increasing or decreasing truck parking, such as type of parking, location, corridor, etc.

Another possibility is to segment the models by type, and estimate different values of ρ that correspond to different circumstances. For example, one ρ could represent travel on a certain highway and another ρ could represent travel on a different highway).

It is difficult, if not impossible to know beforehand which regression model will work the best. For this reason, we have described different options that will be explored. If none of the regression models produce improved demand estimates , we will revert to using the comparison of averages approach described in the previous section.

5. Calculation of Truck Parking Demand (Step 3)

5.1 Current Demand Estimation

The GPS database will be analyzed to count the number of parking events recorded at all of the designated and undesignated locations identified previously, for every hour of the day. Then, the expansion factors will be used to extrapolate to the number of trucks represented in real life.

5.2 Forecasted Demand Estimation

A 2040 forecasts will be developed by assuming that truck parking demand is proportional to the truck volumes on the roads. The growth in truck volumes will be obtained from the growth in freight tonnage forecasted by the SWIM model maintained by ODOT, which assigns freight flows to the corridors in Oregon and uses economic forecasts to project freight volumes. It will be assumed that no substantial changes to the HOS regulations will be implemented within the forecast period.

5.3 System Metrics

We will explore the use of the following metrics for use in the analysis:

Supply Metrics

- Average supply of parking spaces per centerline mile of highway
- Average supply of parking spaces per type, and amenities offered

Demand Metrics

- Average peak period parking demand per centerline mile of highway
- Average peak period parking demand per parking type, per major amenities available
- Average peak period parking demand for peak day of the week per centerline mile of highway
- 95th percentile peak period parking demand
- Proportion of facilities with 100% utilization
- Average demand for undesignated parking per centerline mile of highway (to identify unmet needs)
- Average time spent parking per time spent driving

System Performance Metrics

- Average shortfall of peak parking demand per centerline mile of highway, in 2019
- Average shortfall of peak parking demand per centerline mile of highway, in 2040
- Average shortfall of peak parking demand per roadway segment, in 2019
- Average shortfall of peak parking demand per roadway segment, in 2040
- Average time spent looking for overnight parking per roadway segment

It is difficult to know which metric will best capture parking needs before working with the data.

6. Conclusion

This Memorandum describes an approach to estimate truck parking demand that avoids some of the pitfalls of previous studies and leverages the data available in Oregon. The approach will be finalized in April and the analysis will be implemented this spring. The results are anticipated to be available this summer and will be shared with the TAC when complete.