Introduction

Truck drivers are faced with a critical shortage in truck parking due to growth in commercial vehicle truck travel on our nation's roads. The growth in truck travel has created a considerable parking challenge. The five-axle trucks that drive the nation’s highways are difficult to park, and require dedicated spaces designed for trucks to be parked legal. While the supply of parking has not kept up with growth in truck travel, truckers also face an information problem with respect to finding parking. Truckers must guess where to go, and if they are wrong, may face long distances to find the next location with dedicated legal parking. A fatigued driver that must drive to search for a parking place can become not only a safety issue but also an environmental issue because the search for truck parking generates excess and unnecessary diesel emissions. Truck drivers that park away from amenities and electrification infrastructure generally must idle their truck continuously to power the interior cabin.

Information on where truck parking is available can mitigate the asymmetric information problem that truckers face with respect to finding parking. It would greatly enhance the ability of truckers to find safe, legal parking where they can rest. While information on current parking availability is useful for informing truckers of current parking availability, TSRC is seeking to advance the quality of this information by developing analytical methods to generate forecasts of truck parking availability based on historical data collected from sensing systems placed at truck stops. Forecasts of truck parking availability in the future are relevant to truckers that are distant from targeted truck stops and want to have an estimate as to what parking availability will likely be when they arrive. Forecast models are developed using historical records of activity data collected on the highway and at the truck stops.

The goal is to provide drivers with parking information prior to arriving at their destination. Truck drivers can access the information about forecasted and historical parking availability via the Internet or a mobile device. Over time, forecasted parking information may be able to account for seasonal and economic variations. This project shall explore the application of truck parking forecasting using existing sensing resources and data as derived from existing infrastructure deployed on the I-5 corridor in California.

This document outlines a general methodological approach for estimating, forecasting and displaying the availability of truck parking at truck stops that continuously record parking information locally, and transmit historical information to a central database. The document describes how the system could operate using a variety of sensing and reporting infrastructure.
While the context of this application is truck parking, the system process and approach is generalizable to any parking availability system, including urban parking, suburban parking, as well as supply and logistics operations, and other parking applications.

**System Components and Needs**

A system that produces truck parking estimation and forecasting requires a number of general system needs to produce and render parking information so that it is usable by truck drivers. The system needs include the following:

1) **Source of Parking Information (SPI):** The system requires a source of parking information, which describes parking availability at the location of interest. The source of parking information records data on availability at some discrete interval. The interval of recording can vary from very high frequency recording, such as multiple times per second, to lower frequencies, such as once a minute, once every several minutes (2, 3, 4, etc.), once an hour, or every several hours or less frequently. The quality of information improves as the frequency of information recording is higher. This source can be a human kept inventory of parking activity or can be rendered by the sensors that detect and record information about the parking activity. The SPI may store the data locally and forward data to a central database for use at a later time. The SPI may also transmit data within a local area network for storage and processing on a computer positioned on-site with the SPI (described below).

2) **A Central Database Server (CDS):** The central database of the system receives and stores information forwarded from the source of parking information at each location. The time stamp at which the CDS receives the data, and the time stamp of the data itself may be different. Both may be recorded, or the CDS may simply record the time of receipt.

3) **Parking Availability Estimation and Forecasting Algorithm (PAEFA):** A parking availability estimation and forecasting algorithm is produced using the historical information archived within the Central Database. The PAEFA can also draw from other sources of information, such as the time of day, the location, the time of year, and other outside fixed and variable attributes to produce an estimate of the parking availability at the location. Using historical information, the PAEFA may produce an estimate of parking availability for the near present time as well as over a spectrum of future time. For example, the PAEFA may provide an estimate of parking availability at time intervals in the future such as a couple minutes in the future, 5 minutes in the future, 15 minutes in the future, 30 minutes in the future, 1 hour in the future, 2 hours in the future, etc. The PAEFA may be modified and adjusted as new historical information from the SPI is acquired over time.
4) **Parking Ground Truth Recalibration System (PGTRS):** Parking locations within the system may require recalibration of parking availability information. Sensing systems at some locations will inevitably be subject to inaccuracy. For those systems that track activity via the counting of entrances and exits, errors in sensing can accumulate and propagate, which cause growing inaccuracies in future information. Such locations may require recalibration of information via a ground truth assessment of parking availability information. This information can be produced through a variety of ways, but ultimately the recalibration system renders a count of vehicles that is reliably accurate. Given prevailing technology of the day (2013), the only guaranteed accurate way to produce a count of vehicles at the parking location is through a human count. The human count could be produced through the evaluation of pictures sent by a single or set of cameras that provide a comprehensive view of the lot. These picture(s) would then be reviewed by a staff person of the system to count the trucks and evaluate the correct count of the system. The system count at the location is then reset to the correct count, with a time stamp effective and equivalent to the time stamp of the photos. The photos therefore need to be taken at or near the same time. Sensing data received after this effective time stamp can then adjust the estimated count from this recalibrated value. Recalibration may also be completed by a recount of vehicles on-site by a human on-site. If the lot closes daily and clears out, this event can also serve as a recalibration if the system is informed of it.

5) **Remote Computer & Storage (RCS):** Depending on the system design of the SPI, a remote computer and accompanying storage capacity may be needed locally on-site. The RCS has several functions. It can serve as an intermediate storage for sensing data, recalibration data, and data processing. Data from the SPI and the PGTRS are sent to the RCS over the local area intranet or network, with all devices connected to the same router. The RCS is then responsible for forwarding information onto the CDS. The RCS serves as the on-site brains of the location, and is remotely accessible. It can be used for on-site maintenance and troubleshooting as well as equipment management and operation. The RCS may be used for on-site error correction applications, availability estimation, and on-site forecasting. The products of these data processing operations may be sent to the CDS. In some special circumstances, the RCS is not needed or is redundant to existing systems already present.

6) **Information Delivery System (IDS):** The estimated parking availability information forecasted by the PAEFA using data from CDS is then projected to the Information Delivery System. The IDS may constitute a variety of the delivery mechanisms. Standard information delivery mediums of the present day include websites that can project information to desktop, laptops, and mobile platforms (such as smart phones and tablets). In mobile apps, which are stand-alone software applications built for mobile
platforms constitute another forum for projecting estimated and forecasted parking availability information. Further forums for the delivery of information could include automated voice activated systems, such as interactive voice response system on phones, speech to text systems, and human to human customer service systems. In addition, information may be delivered to changeable message signs along the highway. Information may be delivered by wire, wirelessly, or by line of sight to the user depending on the platform. The IDS manages the query of the data from the CDS. The IDS may query estimates of parking over a spectrum of time. Upon request of the user, the IDS may query historical parking information for a location, it may also query estimates of future parking availability for display to the user.

7) **System Operations Computer Cluster (SOCC):** The SOCC is a single or set of computers that centrally manage the system data. The SOCC may be distributed or centralized. Collectively, the SOCC communicate with the RCS to send commands to the parking locations SPI and recalibration cameras (PGTRS). The SOCC also implements the PAEFA using data stored on the CDS. The SOCC is responsible for sending the output from the PAEFA to the IDS. This may occur through direct transmission to the IDS or may occur through an SOCC data write to the CDS, which is retrieved by the IDS. The SOCC manages the implementation of algorithms to generate the estimation of availability data as well as forecasts of availability in the future.

The system shall be subject to repeated verification of accuracy through continuous ground truth assessments made by video of parking activity at the location or by a human inventory of parking activity that is completed on a continuous or temporary basis. The verification process helps inform the algorithms that are subsequently used in the PAEFA, but verification is not part of the day-to-day operations of the system. Using the information from the verification process, as well as other exogenous attribute data available, the PAEFA can continuously generate forecasted estimates of parking availability over a spectrum of time. The verification process may be repeated throughout the system operation, such the PAEFA can be improved over time or adapt to new conditions. The system may operate continuously, using historical activity data derived from the SPI and CDS, and delivering historical information as well as parking forecasts to users via the IDS.

**Schematic of System Designs**

This section provides a schematic of the system design, in the context of parking at truck stops. However, the application could apply to urban parking in the context of on-street or off-street parking, as well as the suburban context for both passenger and freight vehicles. The first schematic (Figure 1) describes the system in the context of using sensors as the SPI. The second schematic (Figure 2) describes the system in the context of using human inventory management as the SPI. This secondary system involved human continuously tracking parking and reporting this information to the RCS and/or forwarded to the CDS. The third system schematic (Figure 3)
describes a system in which human-based inventory management forwards data to a third party system, and the system later retrieves the information for processing and delivery to the IDS.

**Figure 1: Schematic of Parking Forecasting System with Sensing through Sensors**

In Figure 1, sensors at the parking location report information to the internet access point and RCS. The sensors may count entrances and exits, or they may identify spots. The information is stored on the RCS, and later forwarded to the CDS. The SOCC then processes information on the CDS using various algorithms defined within the PAEFA. The PGTRS is used periodically to check and make sure the information reported by the SPI is correct, and the system allows adjustments on the CDS is review of the PGTRS finds large discrepancies. The IDS communicates with the CDS to query information desired by the user (Driver), and this communication may be supported by the SOCC directly or indirectly.
In Figure 2, an inventory management system at the parking location reports information to the internet access point and RCS. The inventory management system is generally a check-in, check-out system, where each vehicle entering the system is registered in a database. The information is stored on the RCS, and later forwarded to the CDS. The SOCC then processes information on the CDS using various algorithms defined within the PAEFA. The IDS communicates with the CDS to query information desired by the user (Driver), and this communication may be supported by the SOCC directly or indirectly.
In Figure 3, an inventory management system at the parking location reports information to a third party database. The SOCC later queries the third party database, processes in the information and sends it to the CDS for storage. The IDS communicates with the CDS to query information desired by the user (Driver), and this communication may be supported by the SOCC directly or indirectly.

**Summary**

This document serves as an overview of the design of a system that produces estimates and forecasts of parking availability information. Estimates and forecasts are based on historical data of parking activity. Algorithms and formulas based on this data can be used to provide an estimate of parking availability at time intervals in the future such as 5 minutes in the future, 15 minutes in the future, 30 minutes in the future, 1 hour in the future, 2 hours in the future. The algorithm can also provide estimates of parking availability contemporaneous parking availability based on data from prior activity. The IDS may present the user with information on
earlier parking status as well as estimates of future parking status as derived from historical information.