FINAL REPORT

Model Development For National Assessment of Commercial Vehicle Parking

Prepared for

Federal Highway
Administration
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101

FOREWORD

This report provides detailed technical documentation supporting the Report to Congress on the study called for in Section 4027 of the Transportation Equity Act for the 21st Century to "determine the location and quantity of parking facilities as commercial truck stops and travel plazas and public rest areas that could be used by motor carriers to comply with Federal hours of service rules." The report details the development and validation of a model for estimating commercial truck parking demand.

Janet A. Coleman	Michael F. Trentacoste
Director, Office of Safety Programs	Director, Office of Safety
Safety Core Business Unit	Research and Development

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The objective of this research was to estimate the extent and geographic distribution of truck rest parking supply and demand along the National Highway System in accordance with Section 4027 of the Transportation Equity Act for the 21st Century. This report presents the development, calibration, validation, and application of the truck parking demand model used to meet the Section 4027 requirements.

The parking demand model developed for this study estimates parking demand for a highway segment (defined by the analyst) rather than a single parking facility. The model incorporates a variety of factors known to affect the demand for truck parking, which include: traffic engineering factors (e.g., annual average daily traffic, travel time, peak hour factors), truck driver behaviors (e.g., time spent loading/unloading, time spent at home, time spent resting at shipper/receiver), and Federal hours-of-service regulations (e.g., a maximum 70 hours on duty in eight days). A step-by-step method for selecting analysis segments and applying the model is presented. The first step in alleviating parking shortages is to identify the locations where shortages exist. The demand model is a good first step in achieving this goal. Overall, the model produces acceptable estimates of parking space demand. For 29 segments where parking counts were conducted, the model error was only –2 percent, an estimate within 269 spaces of the observed parked trucks. However, the model is not microscopic enough to always accurately predict segment-specific demand. This is because the model does not consider a number of factors that can affect the local distribution of demand (e.g., proximity to distribution centers that results in “staging,” proximity to other parking facilities that absorb demand, and factors that affect the short-haul/long-haul ratio). Because of these limitations, the model should be used as a guideline for identifying possible locations of parking shortages that can be evaluated more carefully through additional study and field observations.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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EXECUTIVE SUMMARY

This report summarizes activities and research that were undertaken as part of a study mandated by the Transportation Equity Act for the 21st Century (TEA-21). Section 4027 of TEA-21 specifies:

> *The Secretary shall conduct a study to determine the location and quantity of parking facilities at commercial truck stops and travel plazas and public rest areas that could be used by motor carriers to comply with Federal hours-of-service rules. The study shall include an inventory of current facilities serving the National Highway System, analyze where shortages exist or are projected to exist, and propose a plan to reduce the shortages.*

This study involved the conduct of the following four tasks:

- Plan, organize, and provide logistical support for a meeting to bring together key national stakeholder groups as a kick-off to the study.

- Estimate the extent and geographic distribution of truck rest parking supply, demand, and shortages (current and projected) along the National Highway System (NHS) using existing national and State inventories and studies.

- Determine how commercial vehicle drivers plan for and address their parking needs for both short-duration and Federal hours-of-service rest; how drivers select when, where, and at what facility they park; and how and why drivers decide to use public versus private parking facilities.

- Provide technical support to public-private partnerships in various States in carrying out their initiatives and preparing their plans of action.

This report addresses the second of these tasks by describing the development, calibration, and application of the truck parking demand model used to estimate truck rest parking demand. This parking demand model estimates parking demand for a highway segment rather than a single parking facility. The model incorporates a variety of factors known to affect the demand for truck parking: traffic engineering factors (e.g., annual average daily traffic (AADT), travel time, peak-hour factors), truck driver behaviors (e.g., time spent loading/unloading, time spent at home, time spent resting at shipper/receiver), and Federal hours-of-service regulations (e.g., a maximum of 70 hours on duty in eight days). A step-by-step method for selecting analysis segments is presented along with data requirements, parameter values, and a sample model application.

About half of the model parameters were derived from survey responses from over 2,000 drivers across the United States. The other half of the model parameters were calibrated using overnight field observations of parked trucks in eight States: Arkansas, Georgia, Idaho, Mississippi, Missouri, Pennsylvania, Tennessee, and Virginia. Observational studies were performed on 29 segments of highway in these eight States representing four regions and ten corridors. By comparing model estimates to the field counts of parked trucks, two model parameters were calibrated: the long-haul peak parking factor (PPF_{LH}) and the short-haul to long-haul ratio (P_{SH}/P_{LH}) ratio.

The parking demand estimates produced by the model are highly variable at the segment level. For example, the model estimates are within ±10 percent of the observed parked trucks for only 4 of the 29 segments (14 percent), ±20 percent for 11 of the 29 segments (38 percent), and ±30 percent for 20 of the 29 segments (69 percent). At the corridor level, on the other hand, the model is much more accurate; model estimates are within ±8 percent of the observed parked trucks for six of the ten corridors (60 percent) and ±20 percent for eight of the ten corridors (80 percent).

The variance at the segment level can be attributed to several factors. One factor is that the model does not take into account the geographic distribution of available truck parking spaces. Although the amount of available parking does not affect the actual demand, the geographic distribution of the supply will affect where the demand is met. Therefore, when field counts were compared to model estimates, it is not surprising that, in some cases, the estimates for one segment were too low, while the estimates for the next segment were too high. Additional research into how to add a factor to the model that represents the distribution of supply would make the model more accurate at the segment level and more useful for local planning. In addition, the use of only two short-haul to long-haul ratios (i.e., .36/.64 for urban segments and .07/.93 for rural segments) may not adequately reflect the variations across regions and corridors. To better understand the variability in the short-haul to long-haul ratio, origin-destination surveys could be conducted in a variety of locations that represent a range of distances from metropolitan areas.

Nevertheless, the first step in alleviating parking shortages is to identify the locations where problems are likely to exist, and the demand model is a good tool for achieving this goal. Overall, the model produces acceptable estimates of parking space demand, with an error of only -2 percent for the 29 segments where parked truck counts were conducted, which is within 269 spaces of the observed parked trucks.

In conclusion, one of the most powerful features of the truck parking demand model is its ability to estimate future demand so that long-range plans can be formulated. States could use this model to identify locations with possible parking shortages, then, based on local knowledge and field observations, refine the model to better reflect local conditions. The refined model could then be used to make projections of parking demand for long-range planning purposes.

1.0 INTRODUCTION

This report summarizes activities and research that were undertaken as part of a study mandated by the Transportation Equity Act for the 21st Century (TEA-21). Section 4027 of TEA-21 specifies:

> *The Secretary shall conduct a study to determine the location and quantity of parking facilities at commercial truck stops and travel plazas and public rest areas that could be used by motor carriers to comply with Federal hours of service rules. The study shall include an inventory of current facilities serving the National Highway System, analyze where shortages exist or are projected to exist, and propose a plan to reduce the shortages.*

1.1 PURPOSE OF STUDY

The goal of this study was to provide technical support to the Federal Highway Administration (FHWA) in satisfying the requirements of TEA-21 Section 4027. This study of the National Highway System (NHS) extends a study completed in 1996 of commercial driver rest and parking requirements on the Interstate Highway System ("1996 Study").[(1)] The present study involved the conduct of the following four tasks:

- Plan, organize, and provide logistical support for a meeting to bring together key national stakeholder groups as a kick-off to the study.

- Estimate the extent and geographic distribution of truck rest parking supply, demand, and shortages (current and projected) along the NHS using existing national and State inventories and studies.

- Determine how commercial vehicle drivers plan for and address their parking needs for both short-duration and Federal hours-of-service rest; how drivers select when, where, and at what facility they park; and how and why drivers decide to use public versus private parking facilities.

- Provide technical support to public-private partnerships in various States in carrying out their initiatives and preparing their plans of action.

The objective of the stakeholder meeting was to present an overview of the proposed data collection methodology, the parking demand estimation model, and the driver survey being developed as part of this study. A meeting was held in May 2000 to brief approximately 30 attendees representing 15 different stakeholder organizations. Attendees included representatives of Federal and State departments of transportation, enforcement agencies, the motor carrier industry, private truck stop operators, commercial drivers, and safety advocacy groups. The meeting provided the project team with important insight into the factors affecting commercial driver parking needs, sources of information that could be used in the study, and a critical review of the proposed plan for model and survey development and data collection.

The objective of the second task was to develop a parking demand model to assist States in predicting truck parking demand along their highways and to conduct a national assessment of commercial vehicle parking availability by comparing existing and projected demand along segments of the NHS to existing and projected supply. The results of this task, together with a summary of the model development process, are presented in this report.

The third task involved the development of a questionnaire and nationwide survey of truck drivers to determine truck driver parking needs and preferences. The survey sought to determine: 1) how truck drivers plan for and address their parking needs; 2) how they select when, where, and at which facility they park (including public versus private stops); and 3) what drivers think of the adequacy of current parking facilities. The results of the driver survey task are published in a separate report.(2)

In addition to the above tasks, a fourth task was undertaken to provide technical support to public-private partnerships in various States in carrying out their initiatives and preparing plans of action. The results of this partnership support task, which include a compilation of the status reports from the various State partnerships, are presented in a separate report.(3)

1.2 OBJECTIVE OF THIS REPORT

This report documents the results of the task to develop a parking demand model for estimating the extent and geographic distribution of truck rest parking supply, demand, and shortages. The next section briefly reviews previous studies of truck parking issues including the 1996 Study and subsequent studies by individual States. Then, the report focuses on the parking demand estimation model developed for the TEA-21 Section 4027 study, which was used to assess the demand for existing parking and to forecast the availability of commercial vehicle parking along the NHS. Along with an explanation of the model, this document presents supporting research, discusses field studies, and chronicles the process behind the development, calibration, and validation of the parking demand model.

2.0 BACKGROUND

The 1996 Study documented an evaluation of the adequacy of rest parking facilities serving truck drivers using the Interstate Highway System.(1) The study sought to address the perceived need for additional parking through direct observation, interviews, statistical evaluations, and demographic data collection. The research team first assessed the current status of public rest area parking for trucks nationwide and developed analytical models to estimate the demand for truck parking spaces. The comprehensive assessment of public rest areas projected a shortfall of 28,400 truck parking spaces in public rest areas nationwide.

An important component of the 1996 Study was the information obtained from a survey of truck drivers. More than 90 percent of commercial drivers surveyed perceived that there was a shortage of truck parking, particularly for long-term or overnight parking. In addition, the survey results showed some important distinctions between public rest areas and private truck stops. The majority of drivers expressed a preference for public rest areas for short-term parking, while two-thirds indicated a preference for private truck stops for long-term rest needs, thus suggesting a distinction of the facility types in terms of the needs that they serve. Although a survey of private truck stop operators suggested that about one-third planned to expand their parking facilities over the next three years, there was a concern that this additional supply may not fully satisfy the demand for public rest areas if private truck stops and public rest areas are not substitutes for each other.

The conclusion of the 1996 Study was that there was a shortfall in the number of truck parking spaces that could only be remedied by creative strategies geared toward facilitating future rest area spending decisions over the next ten years.

This TEA-21 Section 4027 study updates the 1996 Study evaluation and expands the scope to include the NHS. To obtain input on the TEA-21 Section 4027 study, FHWA sponsored the June 29-30, 1999 Rest Area Forum in Atlanta, Georgia.(4) Attendees included representatives of Federal and State departments of transportation, enforcement agencies, the motor carrier industry, private truck stop operators, commercial drivers, and safety advocacy groups. The summary of proceedings documented issues identified and recommendations made by forum participants, as well as some of the efforts that States have made to improve the availability of public rest areas.

This section summarizes some of the approaches that several States have taken to address the growing demand for safe commercial vehicle parking subsequent to the 1996 Study.

2.1 TENNESSEE

To learn about the parking space occupancy characteristics of trucks, the University of Tennessee conducted nighttime observational studies at all public rest areas in Tennessee for each day of the week.(5) Availability of space in private truck stops near interchanges was also examined. The results of the occupancy studies showed that the rest areas were overflowing with trucks at night, as evidenced by trucks parked along the shoulders of highway exit and entrance ramps, as well as on interchange ramps. While rest areas were overflowing, approximately 30 percent of the private truck parking spaces were not occupied, and the unoccupied private parking spaces outnumbered the trucks parked along the highways by nearly a three-to-one ratio.

To understand why some truck drivers park along the highway when there are available private parking spaces, in-depth interviews were held with five drivers. Opinions of the drivers interviewed were quite consistent. The findings were that private truck stops and public rest areas are not substitutes for each other because they meet different needs. While private truck stops are used when there is a need for fuel, a meal, or other amenities, drivers want to pull over as soon as possible when they feel sleepy. In such situations, they prefer to pull off at the nearest rest area or park wherever they can, even on the shoulders of ramps. In addition, drivers reported that it is difficult to find a convenient space in many private truck stops because the parking is not well designed, and there is a risk of minor accidents and damage when moving in and out of these parking lots (as illustrated in figure 1).

Figure 1. Example of tight parking for trucks.

2.2 MINNESOTA

The Minnesota Department of Transportation (Mn/DOT) conducted several market research studies during 1997 and 1998 to improve the provision of rest area services and to expand their understanding of the views of different market segments.(6) The studies included: motorist usage surveys, focus groups, a statewide telephone survey of rest area usage and satisfaction, and commercial truck usage and nighttime parking demand analysis.

The objective of the nighttime parking demand analysis was to identify rest areas where there was a greater demand for nighttime truck parking than there were available spaces and to document the frequency of this occurrence. Sites were identified as potentially having a parking capacity problem if the average truck parking capacity used was greater than 80 percent, or if the truck parking capacity was met or exceeded three percent of the weekdays or days of the year. Based on these criteria, the study results suggested that 26 of the 50 full-service rest areas operated by Mn/DOT potentially had parking capacity problems.

Mn/DOT conducted another truck study to determine how commercial vehicle operators use the rest areas along I-94 during nighttime hours. (7) Survey hours were from 11:00 p.m. to 7:00 a.m. Monday through Friday during one week. The following data were collected: 1) total vehicles on eastbound I-94 before each rest area, 2) total number of vehicles entering each rest area, 3) arrival time of each commercial vehicle entering the rest area between 11:00 p.m. to 7:00 a.m., and 4) dwell time of each commercial vehicle entering the rest area between 11:00 p.m. to 7:00 a.m. The following results were reported:

- Approximately 14 percent of the commercial vehicles on eastbound I-94 utilized the rest areas.
- Twenty percent of the commercial vehicles surveyed arrived before 11:00 p.m.
- Twenty percent of the commercial vehicles surveyed departed after 7:00 a.m.
- Over the entire week for all rest areas, the oversized lots were at or over capacity 45 percent of the time.
- None of the rest areas were at capacity at 11:00 p.m.
- Almost 60 percent of the commercial vehicles arriving before 11:00 p.m. stayed for five hours or more.
- Of the commercial vehicles arriving between 11:00 p.m. and 7:00 a.m., approximately 20 percent stayed in the rest area less than four minutes. One in three stayed eight minutes or less during the survey times.

The study conclusions were that commercial vehicle drivers who arrived at the rest areas before 11:00 p.m. tended to be able to find parking spaces. Once parked, they often stayed for most of the night. Commercial vehicle drivers that arrived later in the evening, after the lots were fully occupied, stayed a much shorter length of time. Based on surveyor observation, the drivers would usually pass through the rest areas without stopping, or with only a momentary stop to look for a space, and would continue on after finding nothing available.

2.3 NEW YORK

To meet the needs of the motor carrier industry and other travelers, the New York State Department of Transportation (NYSDOT) conducted research and developed a program to refurbish the public rest area system on interstate-type highways in New York.(8) The NYSDOT rest area program included four components: 1) a departmental rest area policy, 2) a departmental statewide rest area plan, 3) regional rest area plans, and 4) roadway corridor studies. The rest area policy provided for well-maintained, energy-efficient, multi-functional public buildings with climate-controlled rest rooms, hot water, drinking fountains, indoor vending machines, and tourist/travel information. The plan for the parking facilities design was to meet projected future needs and provide lighted walkways, parking areas, and drives. The regional and statewide plans addressed the spacing and number of rest areas, needs of commercial vehicle drivers, and tourist information.

As part of this research, the University of Albany conducted a survey of long-haul tractor-trailer drivers.[9] A sample of 303 drivers were interviewed at roadside safety inspection sites on Route 17 and I-87 in New York State. The results of the survey were as follows:

- Nine out of ten drivers on each road said that more commercial vehicle parking was needed, and that changes were needed in the selection of food and beverages, the layout and spacing of parking, and the number of telephones.
- Although the majority of drivers on each road rated the adequacy of the rest area facilities as "good" or "excellent," over 25 percent said they were "fair" or "poor." Twenty-five percent rated the safety/security of the rest areas to be "fair" or "poor."
- Forty-two and 24 percent of drivers on Route 17 and I-87, respectively, said the distance between rest areas was too great to allow drivers to stop when they want to.
- Winter closings of one or more rest areas would be problematic for over 85 percent of drivers on each road.
- Seventeen and 42 percent of the drivers on Route 17 and I-87, respectively, were Canadian.
- About two-thirds of the drivers on each road drove more than 161,000 kilometers (100,000 miles) per year, and 82 percent said that most or all trips were overnight.
- About two-thirds of the drivers on each road reported that they usually took breaks on that road. Most of the other drivers reported taking their breaks at private truck stops.
- The most common length of daytime rest breaks on Route 17 and I-87 was 10 minutes and 15 minutes, respectively. The most common length of nighttime stops on each road was four hours.

2.4 IOWA

In 1999, the Iowa Department of Transportation was requested by the Iowa General Assembly to conduct a study of Iowa public policy regarding overnight truck parking.[10] In response, the Iowa Department of Transportation formed a Task Force on Commercial Vehicle Parking. Members of the Task Force included stakeholders from corporate and independent trucking firms; representatives from highway user groups, academia, the enforcement community, and the federal government; and the Iowa Department of Transportation. The Task Force developed a list of four issues requiring research. The Center for Transportation Research and Education (CTRE) at Iowa State University conducted the research.

A key recommendation made by CTRE was that the State of Iowa should continue to be in the business of providing some overnight parking, as the Task Force believed that the State could not expect the private sector to meet all overnight parking demands. An additional recommendation was to prioritize locations where unmet demand for overnight parking was greatest, and to ensure future public development of new overnight parking. Several priorities for the development of future public parking spaces were set: 1) evaluate existing public facilities to accommodate more truck parking, 2) use intelligent transportation systems (ITS) solutions or other media to better inform truck operators of the availability of both public and private truck parking spaces, and 3) as existing rest areas are upgraded, try to size parking to meet space demands for a 20-year planning horizon.

2.5 MICHIGAN

The Michigan Department of Transportation and Michigan State University conducted a study of rest areas in the State of Michigan.(11) The study included an inventory and utilization study of 82 rest areas. The inventory included the number of parking spaces, facilities offered, distance from previous rest area and nearest city, operation time and parking time limits, average daily traffic and truck traffic, distance to the next interchange, and number of private parking spaces within ten miles. Observations for the utilization study were made at most of the rest areas along the interstates and U.S. routes in Michigan during the peak overnight hours. The results of the utilization study showed that although a majority of the rest areas were not full (42 percent), some rest areas were overcrowded (19 percent).

In addition, the study included the development of models of rest area utilization in Michigan. The modeling techniques used included regression and discriminant analyses. Regression analyses were run for four time periods (12:00 a.m. to 2:00 a.m., 12:00 a.m. to 4:00 a.m., 4:00 a.m. to 8:00 a.m., and 6:00 a.m. to 8:00 a.m.) using a measure of truck parking space utilization as the response variable and factors such as truck average daily traffic, number of truck parking spaces, parking space layout, and distance to the nearest city as the independent variables.

Results of the regression analyses showed that for 12:00 a.m. to 2:00 a.m., truck average daily traffic was a significant factor in explaining parking space utilization. For 4:00 a.m. to 8:00 a.m., distance to the nearest city was a significant factor in explaining parking space utilization. For 6:00 a.m. to 8:00 a.m., parking space layout was a significant factor in explaining parking space utilization. R-squared values for the linear regression models, however, were rather low (e.g., 0.359, 0.387, and 0.273, respectively). Results of the discriminant analyses show the same three factors found significant in the regression analyses to be positive contributors to truck parking space utilization.

2.6 MARYLAND

In late 1997, the Baltimore region began to address the need for additional truck parking spaces as a result of trucks parking illegally on highway shoulders. The Truck Rest Area Subcommittee was formed to lead this effort and consisted of representatives from the Baltimore Metropolitan Council, the Maryland Department of Transportation, the Independent Truckers and Drivers Association, the National Association of Truck Stop Operators, the Maryland State Police, and private sector participants.(12)

The subcommittee conducted a two-week, nighttime survey of truck parking at public rest areas, private truck stops, park-and-ride lots, and weigh stations along portions of the I-95 and I-83 corridors. Observers recorded the location of trucks parked along shoulders, the time of day, the number of spaces available at truck stops and rest areas in relation to where trucks were parked, and any signs along the highway indicating parking facilities.

Results of the study showed that a number of drivers were parking illegally along the interstates at night, although private truck stops had parking spaces available. Further, within the network of available rest areas, truck stops, park-and-ride lots, and weigh stations, there were enough parking spaces to accommodate current parking needs around the clock. Subcommittee members concluded that factors contributing to the truck drivers' over-dependence upon the public rest areas and the spill-over of trucks onto the highway right-of-way included: ease of public rest area access, less convenient locations of private truck stops, drivers' perceptions that truck stops are full, inadequate signage, and negative reputations of some private truck stops.

Recommendations for improvement have included: increased signage for private truck stops along the I-95 corridor, promotion of an under-used park-and-ride lot for overnight truck parking, distribution of an updated trucker's map, and improved security at various locations. Future efforts may include developing a better system for providing drivers with timely knowledge of available spaces along State highways and stricter enforcement of parking laws.

2.7 KENTUCKY

In 1999, the Kentucky Transportation Cabinet undertook a truck parking study.[13] The study included an extensive effort to count parked trucks overnight along all interstate highways in Kentucky. The data collection methodology used in the Kentucky study is discussed in more detail in the model calibration section of this report.

3.0 ESTIMATING TRUCK PARKING DEMAND

As part of the 1996 Study, a location-specific parking demand model was developed and calibrated to assess the demand for truck parking at individual rest areas.(1) The structure of this model was not suitable, however, for incorporating the impact of parking provided by private truck stops, as data collected for the development of the model were obtained only from public rest areas. In addition, this model did not adequately account for the spatial distribution of parking opportunities and the effect of these opportunities on demand at a particular location. Therefore, a new model was formulated for this study—a model that bases parking demand on a segment of highway or corridor rather than an individual parking facility.

The corridor model developed for this study uses a somewhat different approach to estimating parking demand. Rather than basing the demand for parking on the characteristics of a parking facility, the model predicts truck parking demand for a highway segment based on total truck-hours of travel and the time and duration of stops. This approach is based on the theory that demand for parking is better explained by hours driving than by attributes of individual truck stops and rest areas. The model also considers the ratio of short-haul to long-haul trucks and the propensity to use public or private parking spaces for different parking purposes. Although the corridor model limits the conclusions that can be drawn about the spaces or amenities required at a specific truck stop or rest area (e.g., the need for lighting, additional parking, etc.), it was considered to be a more appropriate way to estimate truck parking demand for the purposes of this study. Building the modeling framework around this system-level approach also provided a basis to examine the influences of hours-of-service (HOS) regulations as well as driving time and distance on parking demand.

3.1 MODEL DEVELOPMENT

The modeling framework begins by estimating the truck-hours of travel using annual average daily traffic (AADT),[1] percent trucks, length of the roadway segment being analyzed, and the speed limit or average truck speed. The key parameter in the model is the number of hours of parking required by drivers given the number of hours they travel. Thus, Federal HOS regulations have an indirect, but very real, effect on parking demand; the more hours of parking required for a given period of time on the road (i.e., the higher the ratio of parking time to driving time), the higher the estimated parking demand. The model produces a peak-hour estimate of parking spaces demanded for a highway segment.

Because short-haul drivers (i.e., those not making overnight trips) make relatively short stops, parking demand is based on minutes of parking time per hour on the road. For long-haul trips, when an overnight rest stop is required on the road, hours of parking demand are calculated using a ratio of parking time to driving time. This ratio of parking time to driving time takes into account HOS regulations and information from drivers regarding how they use their time throughout a typical week. Then, peak-parking factors are used to convert the 24-hour parking demand into peak-hour parking demand. Using the model, peak-parking demand can be estimated for different percentages of short-haul and long-haul trucks (e.g., 10 percent short-haul

[1] Annual average daily traffic (AADT) is the average 24-hour traffic volume at a given location over a year.

and 90 percent long-haul, 50 percent short-haul and 50 percent long-haul, etc.) and for different driver preferences for parking at public rest areas or private truck stops.

3.2 DATA REQUIREMENTS AND PARAMETER VALUES

This section presents the data requirements for the model and a discussion of how the values for each model parameter were derived, whether based on field studies, driver survey results, professional judgment, or assumption. It is important to keep in mind that these "default" values represent national norms and do not necessarily reflect regional variations. When applying the parking demand model, users are encouraged to select parameter values that represent conditions within their local area.

The data requirements for the model are summarized in table 1. Most of these data are available through the Highway Performance Monitoring System (HPMS) or through a State's own databases and information systems.(14) Model parameters and their values are shown in table 2.

Table 1. Data requirements for truck parking demand model.

Model Variable	Description
L	Length of highway segment (km)
AADT	Annual average daily traffic (vehicles per day)
P_t	Percent of daily traffic consisting of commercial trucks
S	Speed limit of highway or average truck speed (kph)

Because travel demand is variable, traffic engineering analyses generally focus on the peak periods of travel (e.g., peak hour of the day, peak month of the year, etc.). Variation of traffic by month or season is primarily a function of the type of route and kinds of activities present in the area. For example, highways serving winter resort areas peak during winter months, while highways serving agricultural activities peak during the summer months. Due to proximity to a metropolitan area, urban routes tend to show less variation in traffic by season then do rural routes. For the model, a seasonal peaking factor of 15 percent (1.15) was used and represents the peaking characteristics of all vehicles (i.e., not specific to trucks).

The short-term parking duration per hour traveled was assumed to be five minutes, which results in one 40-minute stop during an 8-hour shift. This assumption was based on professional judgment and information obtained from talking with drivers about their typical stopping patterns.

Table 2. Demand model parameters.

Model Variable	Description	Default Value
F_S	Seasonal peaking factor	1.15
D_{ST}	Short-term parking duration per hour traveled (min/hour)	5
$T_{DRIVING}$	Maximum hours driven per week	70
$T_{LOAD/UNLOAD}$	Average hours spent loading/unloading per week	15
T_{HOME}	Average hours spent at home per week	42
$T_{SHIPPER/RECEIVER}$	Average hours spent parking for rest at shipper/receiver per week	16
P_{RA}	Proportion of demand for rest area spaces	0.23
P_{TS}	Proportion of demand for truck stop spaces	0.77
P_{SH}	Proportion of total trucks that are short-haul	0.36 or 0.07*
P_{LH}	Proportion of total trucks that are long-haul	0.64 or 0.93*
PPF_{SH}	Peak-parking factor for short-haul trucks	0.02
PPF_{LH}	Peak-parking factor for long-haul trucks	0.09

*Values depend on proximity of analysis segment to a metropolitan area: 0.36/0.64 for segments within 320 kilometers (200 miles) of a city of 200,000 people or more, 0.07/0.93 otherwise.

A national survey of commercial truck drivers was undertaken in another task of this study and is documented in a separate report.(2) The survey was administered to over 2,000 truck drivers in select regions across the United States. Survey responses were used to determine truck drivers' needs, preferences, and travel patterns (e.g., why, when, and where they park). This information was used to calibrate several of the parameter values in the model so that they would more accurately represent drivers' behaviors and travel patterns. Driver survey results were used to determine values for the following parameters: average hours spent loading/unloading per week, average hours spent at home per week, average hours spent parking for rest at shipper/receiver per week, and the portion of demand for public rest area and private truck stop spaces.

The importance of determining the values of the loading/unloading time, at-home time, and time spent resting at shipper/receiver was to calculate the amount of time a driver demands parking on the road in a typical week. To determine this time, drivers' daily activities including driving, on-duty non-driving time, and time spent at home, must be considered.

To begin, the hours that a driver spends on the road in a week are limited by the Federal HOS regulations. Although there are different regulations for different types of carriers, the majority of long-haul drivers operate seven days a week. In this case, the Federal HOS regulations allow for no more than 70 hours on duty in any period of eight consecutive days.(15)

However, a driver's time is not spent solely driving; they must also spend time at shippers and receivers loading and unloading their trailers. This is considered on-duty, non-driving time. While some drivers will load/unload several times per week, others may do so only once per week. The average hours spent loading/unloading the truck (whether the driver actually loads/unloads or waits for it to be done) was determined from a question that asked drivers how many hours, on average, per week they spend loading or unloading their trucks. The average response to this question was approximately 15 hours per week.

When drivers are off duty, they are sometimes able to return home. While some drivers are home every weekend, others may not make it home but a few days each month. The average hours spent at home per week was determined from a question on the driver survey that asked drivers how many days, on average, did they sleep at home each month. The average response to this question was 6.7 days per month, which translated into approximately 42 hours in eight days.

Finally, in some situations, drivers are allowed to park for rest at a shipper/receiver prior to loading or unloading. Thus, they are not always looking for long-term parking along the highway. The average number of hours spent parking for rest at a shipper/receiver was determined from a question that asked drivers how many times on average in a typical week they park for long-term rest at a series of different locations. The average response to the "loading/unloading location" question was 2.6 times per week. Anecdotal information gathered from discussions with truck drivers suggests an average of six hours of rest per long-term stop. Using this information from drivers, 2.6 times per week translates into approximately 16 hours per week of rest at shippers/receivers.

From this, the amount of time a driver will demand parking along the highway in a week can be determined by taking the total number of hours in an eight-day period (192) and subtracting the time that drivers spend on-duty driving (70 hours), on-duty not driving (15 hours), off-duty (42 hours), and parking other places than along the road (16 hours). Therefore, the total hours of parking demanded per long-haul truck per week, used for this model, was 49 hours.

The proportions of total parking demand for rest area spaces and for truck stop spaces were derived based on responses to questions in the driver survey regarding where drivers prefer to stop for different activities (e.g., long-term rest, restroom, meal, etc.). Table 3 shows the data from the survey and illustrates how the data were used to derive the values for the proportion of demand for rest area and truck stop spaces. The values were derived as follows: 1) the number of driver responses for each preference category (i.e., rest area, truck stop, no preference) was weighted according to the average amount of time spent parking for each activity (thereby converting number of drivers into number of truck-hours of parking according to preference); 2) the truck-hours of parking were then summed for each preference category; 3) the truck-hours of parking in the "no preference" category were then divided evenly between the rest area and truck stop preference categories; and 4) the total truck-hours of parking for rest areas and truck stops were then divided into the overall total truck-hours of parking. This process resulted in values for the proportion of parking demand for rest area and truck stop spaces of 0.23 and 0.77, respectively.

Table 3. Derivation of the proportion of parking demand for public rest areas and private truck stops.

a. Number of drivers reporting preference for rest areas and truck stops by activity

Activity	Average Time for Activity (hours)	Preference for Rest Area (# of drivers)	No Preference (# of drivers)	Preference for Truck Stop (# of drivers)
Restroom	0.25	208	334	222
Eat a meal	1.00	8	63	668
Quick nap	1.00	328	287	143
Extended rest	5.00	47	108	593
Vending machines	0.25	227	400	111
Phones	0.25	138	340	276
Travel information	0.25	85	370	278

b. Truck-hours of parking at rest areas and truck stops by activity (# of drivers reporting preference multiplied by average time for activity)

Activity	Preference for Rest Area (truck-hours)	No Preference (truck-hours)	Preference for Truck Stop (truck-hours)
Restroom	52.00	83.5	55.50
Eat a meal	8.00	63.0	668.00
Quick nap	328.00	287.0	143.00
Extended rest	235.00	540.0	2965.00
Vending machines	56.75	100.0	27.75
Phones	34.50	85.0	69.00
Travel information	21.25	92.5	69.50
Total truck-hours of parking	735.50	1251.0	3997.75

c. Proportion of parking demand for rest areas and truck stops

Facility	Demand (truck-hours)	Proportion of Total Demand
Rest Areas	735.5 + 0.5*1251 = 1361	1361/5984.25 = 0.23
Truck Stops	3997.75 + 0.5*1251 = 4623.25	4623.25/5984.25 = 0.77
Total	5,984.25	1.00

The driver survey conducted for this study, as well as several of the State surveys reviewed at the beginning of this report, indicated that in general, drivers prefer to use rest areas when making a short stop (to make a phone call, get a snack, or use the restroom), because they are more convenient to the highway than truck stops. On the other hand, survey responses indicated that most long-haul drivers prefer to make their long-term rest stops in truck stops, because they provide more services (fuel, meal, showers) than rest areas.

The proportion of total trucks that are short-haul and long-haul and the long-haul peak parking factor were calibrated using data from field surveys. The calibration of these parameters is discussed in detail in a later section titled, Truck Parking Demand Model Calibration.

3.3 PARKING DEMAND MODEL

This section presents the parking demand model in a step-by-step fashion, referring to table 1 and table 2 where data and parameter values are required as input to the equations. Table 4 lists and describes the terms calculated by each of the 12 equations in the step-by-step model process. Once again, analysis is done at the segment level.

Table 4. Terms calculated in step-by-step model process.

Equation Number	Term Calculated	Description of Term
1	V_t	Seasonal peak daily truck volume (trucks/day)
2	TT	Average truck travel time (hours/truck)
3	THT_{SH}	Daily short-haul truck-hours of travel (hours/day)
4	THT_{LH}	Daily long-haul truck-hours of travel (hours/day)
5	THP_{SH}	Daily short-haul truck-hours of parking demand (hours/day)
6	THP_{LH}	Daily long-haul truck-hours of parking demand (hours/day)
7	PHP_{SH}	Peak-hour short-haul parking demand (trucks or spaces/hour)
8	PHP_{LH}	Peak-hour long-haul parking demand (trucks or spaces/hour)
9	$PHP_{SH, RA}$	Peak-hour short-haul parking demand at rest areas (trucks or spaces/hour)
10	$PHP_{SH, TS}$	Peak-hour short-haul parking demand at truck stops (trucks or spaces/hour)
11	$PHP_{LH, RA}$	Peak-hour long-haul parking demand at rest areas (trucks or spaces/hour)
12	$PHP_{LH, TS}$	Peak-hour long-haul parking demand at truck stops (trucks or spaces/hour)

The first step in the parking demand estimation is to calculate the seasonal peak daily truck volume using the AADT, the percent trucks, and the seasonal peaking factor. The *seasonal peak daily truck volume*, V_t, is expressed in trucks per day:

$$V_t = AADT \times P_t \times F_s \qquad (1)$$

where AADT = annual average daily traffic (vehicles/day)
P_t = percent of total traffic that is trucks
F_S = 1.15, seasonal peaking factor

Next, using the length of the analysis segment (defined by the analyst) and the speed limit or average truck speed, the *average truck travel time*, TT, for the segment is calculated in hours per truck:

$$TT = \frac{L}{S} \quad (2)$$

where L = analysis segment length (km)
S = speed limit or average truck speed (kph)

Then, using the daily truck volume calculated in equation 1, the truck travel time calculated in equation 2, and the proportion of trucks that are short- and long-haul, the total *daily truck-hours of travel*, THT, for short-haul and long-haul trucks can be estimated:

$$THT_{SH} = P_{SH} \times V_t \times TT \quad (3)$$

$$THT_{LH} = P_{LH} \times V_t \times TT \quad (4)$$

where P_{SH} = proportion of total trucks that are short-haul
P_{LH} = proportion of total trucks that are long-haul

After the total daily truck-hours of travel on the segment have been computed, the short-haul truck-hours of parking per day, THP_{SH}, can be estimated based on the time parking per time driving. Using the default value for duration of short-term stops (i.e., a driver will need to stop an average of five minutes for every hour of driving) and the truck-hours of short-haul travel calculated in equation 3, the *daily short-haul truck-hours of parking demand*, THP_{SH}, can be estimated:

$$THP_{SH} = \frac{D_{ST} \times THT_{SH}}{60} = \frac{5 \times THT_{SH}}{60} = \frac{THT_{SH}}{12} \quad (5)$$

where D_{ST} = duration of short-term stops per hour traveled (min/hour)

For long-haul drivers, HOS regulations affect the number of hours they must spend parking in a given period of time. As previously stated, long-haul drivers must spend eight hours parking after ten hours of driving, and cannot be on duty more than 70 hours in eight consecutive days. The parking time per week can be computed by subtracting the maximum number of hours spent driving, the average number of hours spent at home, the average number of hours spent loading/unloading, and the average number of hours spent parked to rest at shippers/receivers from the 192 hours in a eight days. Referring to the default values for each of these items in table 2, the parked time per week would be approximately 49 hours (192-70-42-15-16 = 49), and the ratio of parking time to driving time is therefore 49 hours/70 hours (i.e., on average, a long-haul driver will stop for long-term rest approximately 49 hours for 70 hours of driving in a week). In addition, assuming that they will also park an average of five minutes for every hour of driving for purposes other than long-term rest, the daily truck-hours of long-haul travel, calculated in equation 4, can be used to estimate the *daily long-haul truck-hours of parking demand*, THP_{LH}, on the segment:

$$
\begin{aligned}
THP_{LH} &= \frac{\text{Parking time/week}}{\text{Driving time/week}} \times THT_{LH} + \frac{D_{ST} \times THT_{LH}}{60} \\
&= \frac{49 \text{ hours}}{70 \text{ hours}} \times THT_{LH} + \frac{5 \times THT_{LH}}{60} \\
&= 0.70 \times THT_{LH} + \frac{THT_{LH}}{12}
\end{aligned}
\qquad (6)
$$

where D_{ST} = duration of short-term stops per hour traveled (min/hour)

Now that the daily truck-hours of short- and long-haul parking demand for the segment have been estimated, the number of trucks demanding a parking space in the peak hour needs to be determined. This conversion can be made by considering the proportion of the daily truck-hours of parking demand that occurs during the peak hour. Assuming that all trucks occupy a space for at least one hour, the conversion from daily truck-hours of parking to truck-hours per hour can be made with a peak-hour parking factor (PPF). The units of the peak-hour parking demand (PHP) then become trucks or spaces. Default values for short-haul peak parking factor (PPF_{SH}) and long-haul peak parking factor (PPF_{LH}) have been set at 0.02 and 0.09, respectively (a discussion of the calibration is presented in the next section). Using these default values and the truck hours of parking, the *peak-hour short-haul and long-haul parking demand*, PHP_{SH} and PHP_{LH}, respectively, can be calculated:

$$PHP_{SH} = PPF_{SH} \times THP_{SH} = 0.02 \times THP_{SH} \qquad (7)$$

$$PHP_{LH} = PPF_{LH} \times THP_{LH} = 0.09 \times THP_{LH} \qquad (8)$$

where PPF_{SH} = peak-parking factor for short-haul trucks, 0.02
PPF_{LH} = peak-parking factor for long-haul trucks, 0.09

Finally, the total peak-hour parking space demand is distributed between public rest areas (RA) and private truck stops (TS) using preferences established from responses to the driver survey:

$$PHP_{SH,\,RA} = P_{RA} \times PHP_{SH} = 0.23 \times PHP_{SH} \quad (9)$$

$$PHP_{SH,\,TS} = P_{TS} \times PHP_{SH} = 0.77 \times PHP_{SH} \quad (10)$$

$$PHP_{LH,\,RA} = P_{RA} \times PHP_{LH} = 0.23 \times PHP_{LH} \quad (11)$$

$$PHP_{LH,\,TS} = P_{TS} \times PHP_{LH} = 0.77 \times PHP_{LH} \quad (12)$$

where P_{RA} = proportion of demand for rest area spaces
P_{TS} = proportion of demand for truck stop spaces

3.4 NATIONAL ASSESSMENT OF COMMERCIAL VEHICLE PARKING

The national assessment of commercial vehicle parking availability compared existing and projected supply to existing and projected demand along segments of the NHS. This process incorporated three steps that are listed in table 5. The national assessment is documented in a separate report.(3)

Table 5. National truck parking assessment process.

Step Number	Step Description
1	Identify major trucking corridors and select analysis segments
2	Inventory public and private parking space supply for each segment
3	Apply truck parking demand model for each segment and compare to supply

3.4.1 Step 1: Identify Major Trucking Corridors and Select Analysis Segments

The objective of this step was to develop a database consisting of highway analysis segments that make up the major trucking corridors along the NHS in the U.S. For this project, corridors that carried current truck traffic exceeding 1,000 trucks per day were considered to be major trucking corridors. Forecasts were for 20 years into the future (i.e., 2020).

Several sources were used to determine major trucking corridors: 1) the HPMS, 2) the Heavy Commercial Vehicle Flow Atlas of the U.S. NHS (derived from State department of transportation records and selected toll road authorities), and 3) a survey of State DOTs conducted as part of this study.(14,16) After the corridors were identified, shorter analysis segments were selected under the following criteria:

- Truck volume along the segment was relatively uniform.
- For consistency, segments were between 100 kilometers (60 miles) and 320 kilometers (200 miles) in length.
- Logical end points for the analysis segments included: 1) urban-rural transition points; 2) rural interchanges with other major truck routes and bypasses; 3) major cities; and 4) areas with significant truck terminal facilities including ports, warehouses, rail yards, and other intermodal freight transfer points.

After the analysis segments were identified, information on each was entered into a database.

3.4.2 Step 2: Inventory Truck Parking Facilities

The objective of this step was to inventory public and private parking space supply for each analysis segment. A survey of State DOTs and Interstate America's *Truck Stop Directory* were used for this purpose.(17) A survey of State DOTs was administered to obtain information on the number of rest areas operated by the State. Questions regarding the number of truck parking spaces available at each rest area, as well as AADT and percent trucks, were also included on the survey form. The Interstate America's *Truck Stop Directory* is a comprehensive database with location and amenity information of private truck stop/travel plaza facilities. It is updated on an annual basis and describes over 7,000 facilities in the U.S. and Canada that allow commercial vehicle parking.

3.4.3 Step 3: Apply Truck Parking Demand Model

The objective of this step was to estimate parking demand for each analysis segment using the parking demand model. A model application is presented here.

US 000 from Queenstown to Kingsville is a four-lane highway with a posted speed limit of 105 kph (65 mph). This segment of highway is 210 kilometers (130 miles) in length and carries approximately 17,500 vehicles per day, 18 percent of which are trucks. A segment between these two cities was selected for analysis for two reasons: 1) this section of US 000 is known to carry a high volume of truck traffic, and 2) the traffic volume along the segment is fairly uniform. There are three public rest areas and three private truck stops located along the segment.

What is the public/private parking demand along this segment? Is there a surplus or a shortage of public/private parking along this segment?

Problem Summary:

Demand

L	= 210 km (130 mi)
AADT	= 17,500 vpd
P_t	= 18 %
S	= 105 kph (65 mph)

Supply

$Parking_{RA}$	= 17 + 15 + 19	= 51 spaces
$Parking_{TS}$	= 100 + 50 + 125	= 275 spaces

Using equations (1) through (12), the parameter values shown in table 2, and the values from the example shown above, the short- and long-haul parking space demand were calculated:

Seasonal peak daily truck volume:	V_t	= AADT x P_t x F_s = (17,500)(.18)(1.15)	**= 3,623 tpd**
Segment truck travel time per trip:	TT	= L / S = 210/105	**= 2 hrs**
Truck-hours of SH and LH travel:	THT_{SH}	= P_{SH} x V_t x TT = (.36)(3,623)(2)	**= 2,609 veh-hrs**
	THT_{LH}	= P_{LH} x V_t x TT = (.64)(3,623)(2)	**= 4,637 veh-hrs**
Truck-hrs of SH parking demand:	THP_{SH}	= THT_{SH} / 12 = (2,609)/12	**= 217 veh-hrs**
Truck-hrs of LH parking demand:	THP_{LH}	= Parking time/driving time x THT_{LH} + THT_{LH} / 12	
		= 0.70 x (4,637) + 4,637/12	= **3,632 veh-hrs**
Peak-hour parking demand for SH:	PHP_{SH}	= PPF_{SH} x THP_{SH} = 0.02(217)	= **4 veh**
Peak-hour parking demand for LH:	PHP_{LH}	= PPF_{LH} x THP_{LH} = 0.09(3632)	= **327 veh**
SH and LH peak-hour parking demand by facility type:	$PHP_{(SH,RA)}$	= P_{RA} x PHP_{SH} = 0.23 (4)	= **1 veh**
	$PHP_{(SH,TS)}$	= P_{TS} x PHP_{SH} = 0.77 (4)	= **3 veh**
	$PHP_{(LH,RA)}$	= P_{RA} x PHP_{LH} = 0.23 (327)	= **75 veh**
	$PHP_{(LH,TS)}$	= P_{TS} x PHP_{LH} = 0.77(327)	= **252 veh**

The total peak-hour parking demand for public rest areas is 1+75 = **76 trucks**, and the total peak-hour parking demand for private truck stops is 3+252 = **255 trucks**. Considering the supply of parking spaces on this segment, there is a *shortage* of public rest area parking of 51-76 = **(-) 25 spaces**, while there is a *surplus* of private truck stop parking of 275-255 = **20 spaces**.

4.0 TRUCK PARKING DEMAND MODEL CALIBRATION

The next step in the truck parking demand model development process was calibration. Calibration involves estimating the values of various constants and parameters in a model structure. Calibration of model coefficients and constants is usually accomplished by solving the model equation for the parameters of interest after supplying observed values of both the dependent and independent variables, or by manipulating the constants/parameters to obtain a match between known/observed values and the model's estimated values. The calibration of model parameters is an iterative, trial-and-error effort that seeks the parameter values that have the greatest probability of being accurate within a specified "acceptable" error.

In the case of the parking demand model, the observed values were obtained from overnight field counts of parked trucks along interstate highway segments in Arkansas, Georgia, Idaho, Mississippi, Missouri, Pennsylvania, Tennessee, and Virginia. The model's independent variables, as previously discussed, included traffic engineering measures, Federal HOS regulations, and variables derived from drivers' responses to questions regarding actual travel patterns and preferences.

Existing national and State inventories and studies were used, together with the model, to estimate the extent and geographic distribution of truck parking demand and supply along the NHS. Partners, consisting of State DOTs, motor carrier companies, and truck stop operators, examined the model estimates in light of actual observational studies or experience to provide a basis for determining face validity of the results. Where appropriate, model parameters were adjusted to better replicate observed parking demand.

This section details the methodology and data collection procedures for observational studies performed to obtain field data for purposes of calibrating the truck parking demand model. Then, the results of the calibration process are presented and discussed.

4.1 OBSERVATIONAL STUDIES

The purpose of the commercial vehicle parking field survey was to record trucks parked during the peak hour in public rest areas, private truck stops, pull-out areas, interchange ramps, mainline and cross-street shoulders, fueling stations, fast food restaurants, hotels, etc. These field counts were compared to the parking demand estimates from the model during model calibration.

4.1.1 Methodology

Peak demand for long-term truck parking typically occurs in the overnight hours between 10:00 p.m. and 6:00 a.m. The methodology for the observational studies was based on that of surveys conducted by the Kentucky Transportation Cabinet as part of a statewide truck parking study.[13]

In choosing the highway segments for data collection, it was important that they be short enough to allow for counts in both directions during the overnight peak period. Counts in both directions would allow for two counts at every facility at every interchange as well as one count of each rest area, weigh station, and truck pull-out (which are typically accessible from only one side of the roadway). Before conducting the actual study, each segment was driven during daylight hours to verify known parking locations and to identify other potential parking locations for trucks. Where parking spaces were not clearly marked, surveyors asked facility managers or made estimations as to the number of trucks the parking area could accommodate. The surveyors made note of hotels (figure 2), fast food restaurants (figure 3), and large retail stores (figure 4) that had designated truck-parking spaces.

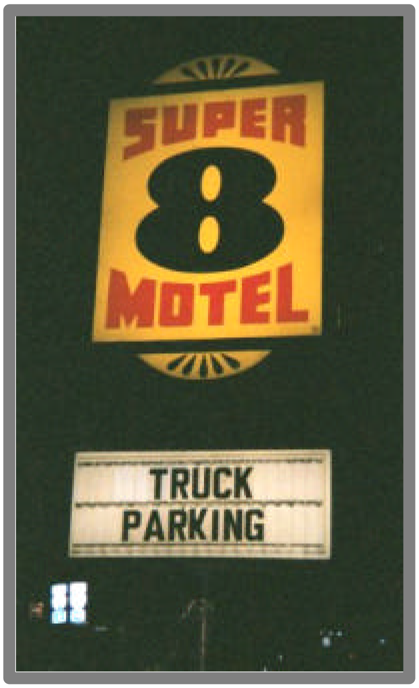

Figure 2. Truck parking signage at a motel.

Figure 3. Truck parking signage at a fast food restaurant.

Figure 4. Example of truck parking available at a large retail store.

While the truck parking areas at some private truck stops may be accessible to passenger cars, others (usually those that have paid parking) have access gates. In these cases, it was necessary for the surveyor to contact a manager to inform him/her of the study, as well as the times that the crew was likely to be back to observe the parked trucks. By informing the truck stop operator of the value of the study, information regarding the approximate number of truck parking spaces could also be obtained.

4.1.1.1 Daylight Observations

A survey crew, consisting of a driver and a field recorder, covered each specified highway segment during the daylight hours of approximately 7:00 a.m. to 5:30 p.m. to locate and record the number of commercial vehicle parking spaces at each interchange. The crew also identified all rest areas and welcome centers that were accessible from only one direction on the highway.

The crew located and counted all truck parking spaces within one-half mile in both directions of the highway. If a sign identified truck parking farther away than one-half mile, the driver located, examined, and recorded parking spaces at that parking facility.

4.1.1.2 Nighttime Observations

The survey crew began at one end of the selected highway segment at approximately 10:00 p.m. and drove to each parking location identified on the inventory forms during the daylight observations. The crew counted all parked trucks, including those that were not at a location identified during the day. The crew continued to drive the segment, counting and recording the number of parked trucks, until reaching the end of the segment. The survey crew then turned around and repeated the same procedure back along the segment in the opposite direction of travel. At locations such as rest areas, welcome centers, interchange ramps, and mainline shoulders, trucks were recorded only once, in the direction of travel.

4.1.2 Survey Administration

The survey was conducted by teaming two individuals experienced in transportation and traffic-related project work. A pilot study was conducted in early October 2000 and subsequent studies were conducted in November and December. Observations were not made during the weeks of the Thanksgiving and Christmas holidays. After the survey crew had completed their observations, the recorded data were input into a spreadsheet for further analysis.

A pilot study was conducted along a 215-kilometer (134-mile) segment [one segment of 95 kilometers (59 miles) and another segment of 120 kilometers (75 miles)] of I-81 in Virginia. Subsequent to the pilot study, observational studies were conducted on six segments of Georgia interstate highway, six segments of Pennsylvania interstate highway, and eight segments of interstate highway in four States around the Memphis, Tennessee area. In addition, results of observations along seven highway segments were obtained from the Idaho DOT.

4.1.3 Field Observation Results

Results of the pilot field observational study on I-81 in Virginia are presented in figure 5. The figure shows the 215-kilometer (134-mile) stretch of I-81 in western Virginia, with each cross-street interchange. At each interchange, the number of observed parked trucks is indicated next to the facility (e.g., truck stop, rest area, fast food, etc.). The numbers shown in parentheses, following the number of trucks observed, are the approximate numbers of spaces available at each facility.

Examination of the diagram shows the 215-kilometer (134-mile) stretch of I-81 to be over capacity. At most of the parking facilities there were more trucks observed parked than there were available spaces (trucks parked around perimeter of facility or in undesignated spaces). In addition, parked trucks were observed on one or more of the ramps at most of the cross-street interchanges. Although all of the public rest areas and most of the private truck stops were full or over-flowing, there were a few spaces available at some fast food restaurants, fueling stations, and shopping centers along the segment.

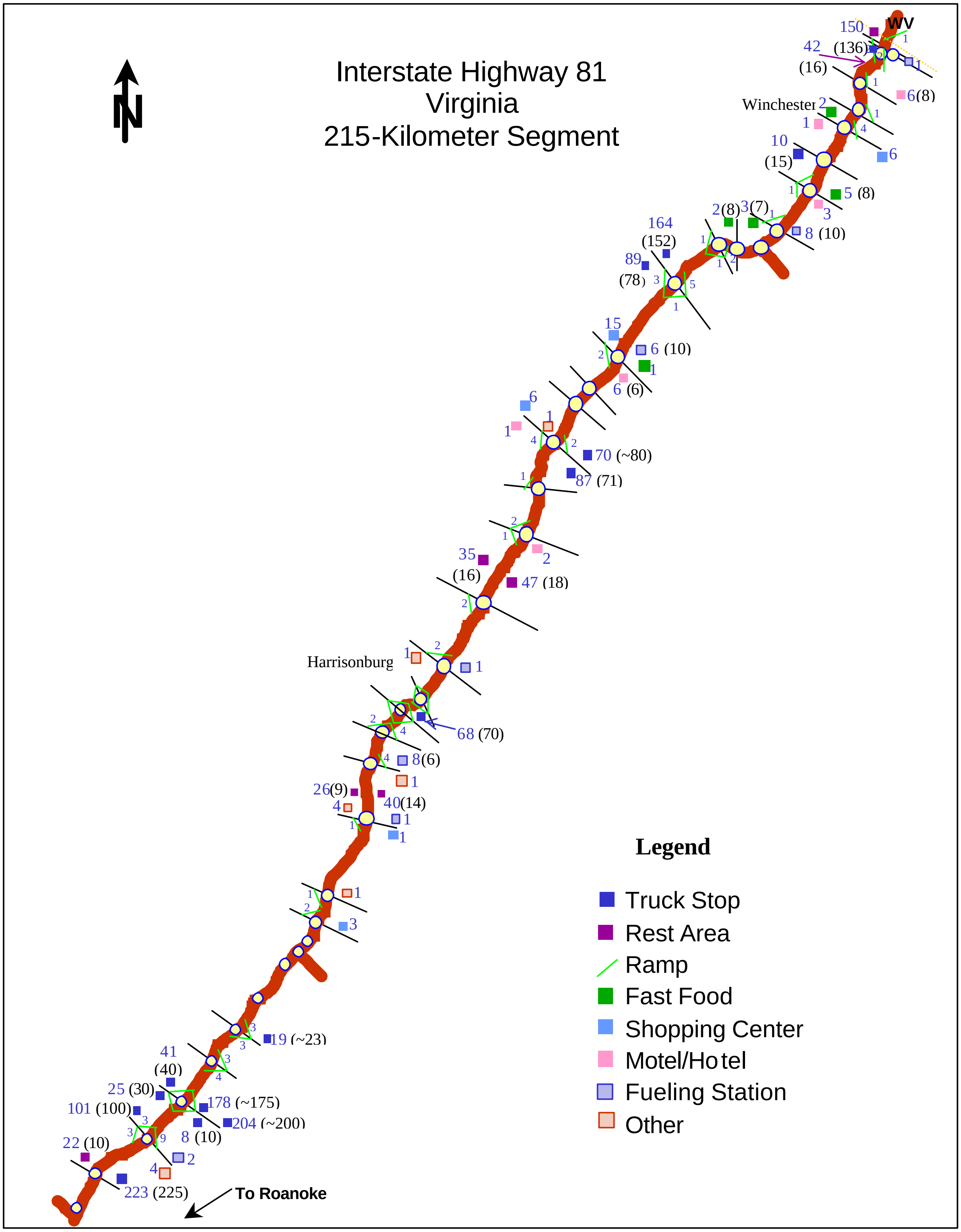

Figure 5. Results of field observational study—location of parked trucks.

4.2 MODEL CALIBRATION

The truck parking demand model was calibrated using truck counts from 29 highway segments. The 29 highway segments are located in eight States across four regions and represent 14 highways along ten corridors. Table 6 gives details about the highway segments.

Two model parameters were calibrated: the long-haul peak parking factor (PPF_{LH}) and the short-haul to long-haul ratio (P_{SH}/P_{LH}). The PPF_{LH} was calibrated, as it is a factor that is not easily measured in the field. When considering peak-hour travel characteristics, traffic engineers sometimes assume that about ten percent of the 24-hour travel demand occurs in the peak hour. While this could be used as a benchmark for calibrating the PPF_{LH}, it is not necessarily safe to assume that the peaking characteristics of truck parking will be the same as those for vehicle travel.

The P_{SH}/P_{LH} ratio (i.e., the proportion of daily truck traffic consisting of short-haul trucks over the proportion of daily truck traffic consisting of long-haul trucks, referred to as the short-haul to long-haul ratio) is not readily known. In addition, there are many factors that might affect the proportion of the daily truck traffic consisting of short- and long-haul trucks. For this study, “short haul” was defined as a trip that could be made without an overnight stay. Thus, the maximum one-way distance for a short-haul trip would typically be between 320 kilometers (200 miles) and 400 kilometers (250 miles), depending on the speed traveled, the length of the workday, and the number and length of stops made during the trip. With this in mind, it is likely that proximity to a city would result in an increased number of short-haul trips, as many round trips are likely to be made in and around the city within this 320-kilometer (200-mile) to 400-kilometer (250-mile) radius. Outside of this radius, the number of short-haul trips would likely decrease, as there are few places for them to originate and terminate without an overnight stay required. Not only is the proximity to a city likely to affect P_{SH}/P_{LH} ratio, so is the size of metropolitan areas. Larger metropolitan areas are likely to generate more short-haul trips than smaller ones. Although there may be a large range of P_{SH}/P_{LH} ratios, for the model purposes, it was important to narrow the options to just a few that would be based on practical, easy-to-define criteria.

After considerable thought and research into values that might be appropriate for the P_{SH}/P_{LH} ratio, the team decided to conduct an origin-destination (OD) survey to measure an actual value for this ratio in the field. The methodology for the OD study was based on a previous study of commercial vehicle traffic on the Woodrow Wilson Bridge in the Washington, D.C. metropolitan area, which employed a similar technique. That OD survey was conducted at a weigh station along I-95 in Northern Virginia to develop an estimate of the number of through trucks over the bridge.(18) The results, applicable to within a metropolitan area, showed the P_{SH}/P_{LH} ratio to be about .65/.35. Because nearly all of the highway segments defined for analysis in this Section 4027 study were located outside of a city, or have a city at one or both end points, this ratio would not be applicable, as it represents truck traffic on a circumferential route within a major metropolitan area.

Table 6. Highway segments for observational studies.

Region (Near)	Segment	Segment Length (km)	AADT (vehicles/ day)	Percent Trucks (%)
Atlanta, GA	I-20 AL State line to Atlanta, GA	71	40,600	41
Atlanta, GA	I-75 Atlanta, GA to Macon, GA	129	50,000	40
Atlanta, GA	I-16 Macon, GA to Soperton, GA	113	15,000	21
Atlanta, GA	I-16 Soperton, GA to Savannah, GA	138	15,000	21
Atlanta, GA	I-75 Bolingbroke, GA to Cordele, GA	95	44,000	25
Atlanta, GA	I-95 Port Wentworth, GA to Darien, GA	97	35,000	30
Pocatello, ID	I-15 UT State line to MT State line[1]	315	9,840	20
Pocatello, ID	US-20 Idaho Falls, ID to MT State line[1]	159	6,690	13
Pocatello, ID	I-84 OR State line to Mountain Home, ID[1]	145	18,310	28
Pocatello, ID	I-84 Mountain Home, ID to UT State line[1]	299	12,142	38
Pocatello, ID	I-86 Jct. I-84 to Pocatello, ID[1]	101	8,190	29
Pocatello, ID	I-90 WA State line to MT State line[1]	122	17,110	14
Pocatello, ID	US-12 Lewiston, ID to MT State line[1]	277	1,930	18
Harrisburg, PA	I-81 Jct. I-64 to Harrisonburg, VA [1]	95	35,687	31
Harrisburg, PA	I-81 Harrisonburg, VA to WV State line[1]	120	35,687	31
Harrisburg, PA	I-81 MD State line to Harrisburg, PA [1]	104	61,800	28
Harrisburg, PA	I-81 Harrisburg, PA to Frackville, PA [1]	80	61,800	28
Harrisburg, PA	I-81 Frackville, PA to Scranton, PA [1]	93	30,400	28
Harrisburg, PA	I-80 Dubois, PA to Rote, PA [1]	128	25,000	22
Harrisburg, PA	I-80 Rote, PA to Bloomsburg, PA [1]	96	25,000	22
Harrisburg, PA	I-80 Bloomsburg, PA to Scotrun, PA [1]	80	25,000	22
Memphis, TN	I-40 North Little Rock, AR to Brinkley, AR	89	29,133	59
Memphis, TN	I-40 Wheatley, AR to Memphis, TN	95	29,133	59
Memphis, TN	I-40 Memphis, TN to Brownsville, TN	100	40,000	20
Memphis, TN	I-40 Brownsville, TN to Holladay, TN	106	40,000	20
Memphis, TN	I-55 Winona, MS to Batesville, MS	127	25,000	20
Memphis, TN	I-55 Batesville, MS to Memphis, TN	84	25,000	20
Memphis, TN	I-55 Memphis, TN to Blytheville, AR	121	24,520	39
Memphis, TN	I-55 Holland, MO to Bertrand, MO	106	37,254	29

[1]Segment classified as a rural segment.

Therefore, an OD survey for this study was conducted at the Grapevine Inspection Facility, located on the southbound lanes of I-5, approximately 120 kilometers (75 miles) north of Los Angeles, California. This site was selected, as it was close enough to a major metropolitan area to serve a number of short-haul trips, but was far enough away from the city not to serve a majority of short-haul trips (thus being more typical of segments analyzed in this study). The study involved a survey of tractor-trailer drivers as they passed through the scales of the inspection station. All data were collected on July 19, 2000, between the hours of 4:30 and 7:30 p.m.

The methodology relied on members of the survey team approaching truck drivers as they entered a weigh station. The survey team consisted of two data collection crews, with each crew consisting of a transportation analyst and a representative of the California Highway Patrol. Each data collection crew was positioned between two of the three static scales. Trucks entering the weigh station formed a single queue until directed by station personnel to one of the three static scales. As the trucks entered the scales, the enforcement officers signaled the drivers to stop. The analysts then approached the trucks and asked the drivers if they would be willing to participate in a survey that would take approximately 15 seconds to complete. All drivers that were approached agreed to participate in the study. To ensure safety of the motoring public, the station operator monitored ramp congestion as the trucks exited the highway. If the truck queue began encroaching on the mainline, the station operator signaled the crews to cease data collection. During the three-hour study, the survey team was directed to stop collecting data twice, for a total of about ten minutes.

The analysts asked the drivers two questions: "For this trip, what was your city and State of origin," and "What is the city and State of your farthest destination?" Trips were classified as local or short-haul if the distance traveled was less than 400 kilometers (250 miles) one-way, all others were considered long-haul trips. During the 2.5 hours of active data collection, approximately 200 tractor-trailer drivers were surveyed. The study team found the approach to be relatively simple to plan and implement and recommended the methodology as an efficient and reliable technique for collecting origin/destination data to determine the number of short-haul and long-haul trucks along a highway corridor.

Analysis of the OD survey showed that about 38 percent of the trucks were short-hauls and about 62 percent were long-hauls, a P_{SH}/P_{LH} ratio of .38/.62. These results, which could be applied to at least the "urban" analysis segments in this study (i.e., those with a city as an endpoint), were used as a starting point for model calibration.

The next section presents a discussion of the PPH_{LH} calibration. Then, the following section discusses the calibration of the P_{SH}/P_{LH} ratio.

4.2.1 Calibrate Long-Haul Peak Parking Factor

The PPF_{LH} represents the proportion of the 24-hour parking demand that occurs in the peak hour. Numerous studies have shown the peak for truck parking to occur between 10 p.m. and 6 a.m. (See references 5,6,7,11,12, and13.) Few short-haul trucks are expected to be on the road at this time, and the value for PPF_{SH} was set at 0.02 (based on professional judgment). In other words, only two percent of the total short-haul parking demand is predicted to occur in the peak hour. (Note: The peak-hour for short-haul parking demand is likely to occur around 12:00 p.m., when the PPF_{SH} would be much higher.) The PPF_{LH}, on the other hand, is more difficult to estimate. Therefore, to calibrate this factor, the model was run simultaneously for each of the 29 segments in table 6 as well as for corridors formed by combining two or more of the individual segments along the same highway or probable travel route. Figure 6 is an example of the parking demand spreadsheet model with inputs and outputs shown.

The first step was to run the model using a fixed P_{SH}/P_{LH} ratio of .38/.62 (from the field OD survey) and to manipulate the PPF_{LH} to get parking estimates as close to the actual truck counts as possible overall for the 29 highway segments. Table 7 summarizes the model estimates; the observed trucks; and the segment, corridor, regional, and overall errors associated with the model estimates using a calibrated (within one percentage point) PPF_{LH} of 0.11.

Truck Parking Demand Model

KEY:
Italics represent model inputs
Shaded cells represent model parameters

Highway Segment Length	***137***	kilometers	
Annual Average Daily Traffic	***21500***	vehicles per day	
Seasonal Peaking Factor	1.15		
Percent Trucks	***0.25***		
Daily Truck Traffic Volume	6181	trucks per day	
Percent Short-Haul Trucks	0.36	(derived from field observations and model calibration)	
Percent Long-Haul Trucks	0.64	(derived from field observations and model calibration)	
Short-Haul Truck Volume	2225	short-haul trucks per day	
Long-Haul Truck Volume	3956	long-haul trucks per day	
Speed Limit or Average Truck Speed	***105***	kilometers per hour	
Corridor Travel Time	1.30	hours per truck	
Short-Haul Truck-Hours of Travel	2903	truck-hours per day on the segment	
Long-Haul Truck-Hours Travel	5162	truck-hours per day on the segment	
Maximum Hours of Driving per Week	70	(from HOS regulations)	
Avg. Hrs. Driver Spends at Home per Week	42	(derived from survey input)	
Avg. Hrs. Driver Spends Loading/Unloading per Week	15	(derived from survey input)	
Avg. Hrs. Driver Spends Parked at Shipper/Receiver per Week	16	(derived from survey input)	
Ratio of Parked-Time per Week to Driving-Time per Week	0.70		
Short-Haul Truck-Hours of Parking Demand	242	truck-hours per day (based on: 5 minutes of parking per truck-hr traveled)	
Long-Haul Truck-Hours of Parking Demand	4043	truck-hours per day	
Short-Haul Peak Parking Factor	0.02	proportion of the SH parking demand in the peak hour	(professional judgment)
Long-Haul Peak Parking Factor	0.09	proportion of the LH parking demand in the peak hour	(derived from model calibration)
Short-Haul Peak Hour Parking Demand	5	trucks	
Long-Haul Peak Hour Parking Demand	364	trucks	
Proportion of Short-Haul Truck-Hrs Parking in Public Spaces	0.23	1 SH truck-hrs parking demand—public spaces	(derived from survey input)
Proportion of Short-Haul Truck-Hrs Parking in Private Spaces	0.77	4 SH truck-hrs parking demand—private spaces	(derived from survey input)
Proportion of Long-Haul Truck-Hrs Parking in Public Spaces	0.23	84 LH truck-hrs parking demand—public spaces	(derived from survey input)
Proportion of Long-Haul Truck-Hrs Parking in Private Spaces	0.77	280 LH truck-hrs parking demand—private spaces	(derived from survey input)

Corridor Demand and Shortage Analysis	**Private**	**Public**	**Net**
Parking Supply	***300***	***89***	389
Peak Parking Demand	284	85	369
Parking Surplus (+) or Shortage (-)	+16	+4	20

Figure 6. Example of truck parking demand model spreadsheet.

Table 7. Summary of model results—calibrated long-haul peak parking factor of 0.11.

Region	Corridor	Segment	Observed Trucks[1]	Model Estimate[2]	Error
Atlanta, GA	1	I-20 AL State line to Atlanta	807	650	-19%
Atlanta, GA	1	I-75 Atlanta to Macon	859	1,421	65%
Atlanta, GA	1	I-16 Macon to Soperton	186	186	0%
Atlanta, GA	1	I-16 Soperton to Savannah	161	229	42%
Atlanta, GA	1	Corridor Subtotal	2,013	2,486	24%
Atlanta, GA	2	I-75 Bolingbroke to Cordele	641	576	-10%
Atlanta, GA	3	I-95 Port Wentworth to Darien	415	559	35%
Atlanta, GA	1-3	Region Subtotal	3,069	3,621	18%
Pocatello, ID	4	I-15 UT State line to MT State line	427	376	-12%
Pocatello, ID	4	US-20 Idaho Falls to MT State line	54	97	80%
Pocatello, ID	4	Corridor Subtotal	481	473	-2%
Pocatello, ID	5	I-84 OR State line to Mountain Home	763	437	-43%
Pocatello, ID	5	I-84 Mountain Home to UT State line	817	825	1%
Pocatello, ID	5	I-86 Jct. I-84 to Pocatello	92	144	57%
Pocatello, ID	5	Corridor Subtotal	1,672	1,406	-16%
Pocatello, ID	6	I-90 WA State line to MT State line	212	170	-20%
Pocatello, ID	6	US-12 Lewiston to MT State line	64	68	6%
Pocatello, ID	6	Corridor Subtotal	276	238	-14%
Pocatello, ID	4-6	Region Subtotal	2,429	2,117	-13%
Harrisburg, PA	7	I-81 Jct. I-64 to Harrisonburg	1,023	624	-39%
Harrisburg, PA	7	I-81 Harrisonburg to WV State line	817	794	-3%
Harrisburg, PA	7	I-81 MD State line to Harrisburg	1,493	1,076	-28%
Harrisburg, PA	7	I-81 Harrisburg to Frackville	618	827	34%
Harrisburg, PA	7	Frackville to Scranton	480	472	-2%
Harrisburg, PA	7	Corridor Subtotal	4,431	3,793	-14%
Harrisburg, PA	8	I-80 Dubois to Rote	654	421	-36%
Harrisburg, PA	8	I-80 Rote to Bloomsburg	507	316	-38%
Harrisburg, PA	8	I-80 Bloomsburg to Scotrun	546	263	-52%
Harrisburg, PA	8	Corridor Subtotal	1,707	1,000	-41%
Harrisburg, PA	7-8	Region Subtotal	6,138	4,793	-22%
Memphis, TN	9	I-40 North Little Rock to Brinkley	652	979	50%
Memphis, TN	9	I-40 Wheatley to Memphis	808	1,050	30%
Memphis, TN	9	I-40 Memphis to Brownsville	119	440	270%
Memphis, TN	9	I-40 Brownsville to Holladay	740	469	-37%
Memphis, TN	9	Corridor Subtotal	2,319	2,938	27%
Memphis, TN	10	I-55 Winona to Batesville	322	446	39%
Memphis, TN	10	I-55 Batesville to Memphis	158	294	86%
Memphis, TN	10	I-55 Memphis to Blytheville	934	811	13%
Memphis, TN	10	I-55 Holland to Bertrand	594	633	7%
Memphis, TN	10	Corridor Subtotal	2,008	2,184	9%
Memphis, TN	9-10	Region Subtotal	4,327	5,122	18%
All	All	TOTAL	15,963	15,653	-2%

[1]Number of trucks counted during the peak hour in the field observational study.
[2]Estimated trucks demanding a parking space during the peak hour.

A PPF_{LH} of 0.11 resulted in a –2 percent error for the 29 segments combined, an estimate within 309 spaces of the observed parked trucks. However, looking at the regional errors, the model overestimates the observed parked trucks in two of the four regions (i.e., Atlanta, Georgia and

Memphis, Tennessee) and underestimates the observed parked trucks in the other two regions (i.e., Pocatello, Idaho and Harrisburg, Pennsylvania). One possible explanation for these contrary results could be the use of only one P_{SH} /P_{LH} ratio. Examining the segments in each of the regions, it appears that while the segments in Georgia and around the Memphis area are tied to an urban area, the segments in Idaho, Pennsylvania, and Virginia are more rural in nature. Thus, from this initial calibration of the PPF_{LH}, it became necessary to develop a second P_{SH}/P_{LH} ratio, one to represent the more rural segments, where the proportion of short-haul vehicles will be less than on segments that are proximate to an urban area. While no field data were available to determine the P_{SH}/P_{LH} ratio for a rural segment, .01/.90 was chosen as a reasonable value, based on professional judgment, and was used as a starting point for model calibration.

Thus, to recalibrate the PPF_{LH} using two P_{SH}/P_{LH} ratios, a "rule" was set for defining whether a segment was urban or rural. A segment was defined as "urban" if it was within 320 kilometers (200 miles) of a city with a population of 200,000 or more, otherwise it was classified as "rural." This definition was based on the maximum distance that could normally be driven round-trip in one day without an overnight stay and a population commonly associated with a metropolitan area. With segments defined as urban or rural and corresponding P_{SH}/P_{LH} ratios, the PPF_{LH} was recalibrated. Table 8 summarizes the model estimates; the observed trucks; and the segment, corridor, regional, and overall errors with a recalibrated PPF_{LH} of 0.09. Segments defined as rural are noted in table 8.

The errors presented in table 8 clearly show that the use of two P_{SH}/P_{LH} ratios results in better estimates of parking demand, when compared to field counts of parked trucks. While the overall error for the 29 segments is higher than when using only one P_{SH}/P_{LH} ratio (-5 percent compared to –2 percent), the regional estimates are all within ±10 percent of the observed values, and the estimates for eight of the ten corridors are within ±16 percent of the observed values (an error considered to be "acceptable" for most demand modeling exercises). These errors represent a considerable improvement over the corridor and regional errors shown in table 7.

It can be seen that the model results presented in tables 7 and 8 are more accurate at the region and corridor level than at the segment level. This is a result of overestimates and underestimates on successive segments forming a corridor, to some extent, canceling out. This is due to limitations in the model; the model does not consider a number of factors that can affect the local distribution of demand (which are observed in the field counts), such as the distribution of supply. While a driver may have the need to park on one segment, he or she may actually park on the previous or subsequent segment, especially if he or she is in search of a truck stop with a particular brand of fuel or a rest area at which he or she might like to stop. Another factor that might affect where a driver actually parks (as opposed to where the need arises) is where major corridors intersect. Again, a driver may need to park on the segment before the interchange, but may wait until after he or she has changed routes. A third factor that might affect where a driver actually parks is if the driver has to pick up or drop off a load the next day. In this case, the driver may "stage" outside of the area in order to more easily access his or her loading dock the next morning. This would most likely affect those segments that have a city as an endpoint.

It should be noted, however, that the error at the segment level does not necessarily indicate that the demand model is inaccurate when applied to highway segments, but may indicate that the lack of parking spaces on some highway segments creates unmet demand that appears in field observations as unusually high demand on nearby segments with a surplus of parking.

Table 8. Summary of model results—calibrated long-haul peak parking factor of 0.09.

Region	Corridor	Segment	Observed Trucks[1]	Model Estimate[2]	Error
Atlanta, GA	1	I-20 AL State line to Atlanta	807	534	-34%
Atlanta, GA	1	I-75 Atlanta to Macon	859	1,166	36%
Atlanta, GA	1	I-16 Macon to Soperton	186	153	-18%
Atlanta, GA	1	I-16 Soperton to Savannah	161	188	17%
Atlanta, GA	1	Corridor Subtotal	2,013	2,041	1%
Atlanta, GA	2	I-75 Bolingbroke to Cordele	641	473	-26%
Atlanta, GA	3	I-95 Port Wentworth to Darien	415	459	11%
Atlanta, GA	1-3	Region Subtotal	3,069	2,973	-3%
Pocatello, ID	4	I-15 UT State line to MT State line[3]	427	443	4%
Pocatello, ID	4	US-20 Idaho Falls to MT State line[3]	54	115	113%
Pocatello, ID	4	Corridor Subtotal	481	558	16%
Pocatello, ID	5	I-84 OR State line to Mountain Home[3]	763	514	-33%
Pocatello, ID	5	I-84 Mountain Home to UT State line[3]	817	971	19%
Pocatello, ID	5	I-86 Jct. I-84 to Pocatello[3]	92	169	84%
Pocatello, ID	5	Corridor Subtotal	1,672	1,654	-1%
Pocatello, ID	6	I-90 WA State line to MT State line[3]	212	200	-6%
Pocatello, ID	6	US-12 Lewiston to MT State line[3]	64	80	25%
Pocatello, ID	6	Corridor Subtotal	276	280	1%
Pocatello, ID	4-6	Region Subtotal	2,429	2,492	3%
Harrisburg, PA	7	I-81 Jct. I-64 to Harrisonburg[3]	1,023	735	-28%
Harrisburg, PA	7	I-81 Harrisonburg to WV State line[3]	817	934	14%
Harrisburg, PA	7	I-81 MD State line to Harrisburg[3]	1,493	1,266	-15%
Harrisburg, PA	7	I-81 Harrisburg to Frackville[3]	618	974	58%
Harrisburg, PA	7	Frackville to Scranton[3]	480	556	16%
Harrisburg, PA	7	Corridor Subtotal	4,431	4,465	1%
Harrisburg, PA	8	I-80 Dubois to Rote[3]	654	495	-24%
Harrisburg, PA	8	I-80 Rote to Bloomsburg[3]	507	371	-27%
Harrisburg, PA	8	I-80 Bloomsburg to Scotrun[3]	546	216	-60%
Harrisburg, PA	8	Corridor Subtotal	1,707	1,082	-37%
Harrisburg, PA	7-8	Region Subtotal	6,138	5,547	-10%
Memphis, TN	9	I-40 North Little Rock to Brinkley	652	803	23%
Memphis, TN	9	I-40 Wheatley to Memphis	808	861	7%
Memphis, TN	9	I-40 Memphis to Brownsville	119	361	203%
Memphis, TN	9	I-40 Brownsville to Holladay	740	385	-48%
Memphis, TN	9	Corridor Subtotal	2,319	2,410	4%
Memphis, TN	10	I-55 Winona to Batesville	322	366	14%
Memphis, TN	10	I-55 Batesville to Memphis	158	241	53%
Memphis, TN	10	I-55 Memphis to Blytheville	934	665	-29%
Memphis, TN	10	I-55 Holland to Bertrand	594	519	-13%
Memphis, TN	10	Corridor Subtotal	2,008	1,791	-11%
Memphis, TN	9-10	Region Subtotal	4,327	4,201	-3%
All	All	TOTAL	15,963	15,213	-5%

[1]Number of trucks counted during the peak hour in the field observational study.
[2]Estimated trucks demanding a parking space during the peak hour.
[3]Segment classified as a rural segment.

4.2.2 Calibrate Short-Haul to Long-Haul Ratio

The next step in the model calibration was to rerun the model using 0.09 as the fixed PPF_{LH} and to manipulate the urban and rural P_{SH}/P_{LH} ratios to get model results as close to the field counts as possible. Table 9 summarizes the model estimates, the actual counts, and the errors using calibrated urban and rural P_{SH}/P_{LH} ratios of .36/.64 and .07/.93, respectively.

Calibrating the P_{SH}/P_{LH} ratios was a trial-and-error process that involved adjusting the ratios one percentage at a time, one ratio at a time, to balance the model estimates around the observed values. The first step in arriving at the calibrated P_{SH}/P_{LH} ratios was to decrease the urban P_{SH}/P_{LH} ratio slightly to increase the parking demand estimates, as the two urban regions were both underestimated by about three percent before calibrating this ratio (see table 8 for the model errors before calibration and table 9 for the model errors after calibration). Therefore, the urban P_{SH}/P_{LH} was adjusted from .38/.62 to .37/.63 to .36/.64. Adjusting the ratio in this manner resulted in the errors for the Atlanta, Georgia and Memphis, Tennessee regions to go from –3 percent to zero. Examining the corridor errors for these two regions, the model estimates for all three multi-segment corridors are within ±8 percent.

The next step was to adjust the rural P_{SH}/P_{LH} ratio. While two of the corridors in the Pocatello, Idaho region and one of the corridors in the Harrisburg, Pennsylvania region were very closely estimated (within ±1 percent) before calibrating the rural P_{SH}/P_{LH} ratio, the I-80 corridor across Pennsylvania (from Dubois to Scotrun) was largely underestimated before calibrating this ratio. Therefore, the rural P_{SH}/P_{LH} ratio was decreased slightly to increase the parking demand estimates. The rural P_{SH}/P_{LH} was adjusted from .10/.90 to .09/.91 and from .08/.92 to .07/.93. Adjusting the ratio in this manner resulted in the errors for the Pocatello, Idaho region to go from 3 percent to 6 percent and the errors for the Harrisburg, Pennsylvania region to go from –10 percent to –7 percent, an adjustment that results in a better balance of the rural estimates around the observed values. Examining the corridor errors for these two regions, the model estimates for four of the five corridors are within ±20 percent of the observed parked trucks, while three of the five are within ±5 percent. The absolute errors in estimated demand at the segment, corridor, and regional level were 38, 12, and 3 percent, respectively.

The calibrated P_{SH}/P_{LH} ratios resulted in an improved overall error of only –2 percent for the 29 segments combined, an estimate within 269 spaces of the observed parked trucks. The parking demand for eight of the ten corridors was estimated within ±20 percent of the observed parked trucks, the parking demand for seven of the ten corridors was estimated within ±13 percent of the observed parked trucks, and the parking demand for six of the ten corridors was estimated within ±8 percent of the observed parked trucks.

The error in the estimates for the I-80 corridor in Pennsylvania remained large (-35 percent) after model calibration. The model estimates for all three segments of this corridor were more than 20 percent lower than the observed values (while the model much more accurately estimated parking demand for the other corridors). It is possible that there were inaccuracies in the input truck volumes. These inaccuracies could come in the form of low AADTs, low percent trucks, or both.

Table 9. Summary of model results—calibrated short-haul to long-haul ratio.

Region	Corridor	Segment	Observed Trucks[1]	Model Estimate[2]	Error
Atlanta, GA	1	I-20 AL State line to Atlanta	807	550	-32%
Atlanta, GA	1	I-75 Atlanta to Macon	859	1,202	40%
Atlanta, GA	1	I-16 Macon to Soperton	186	158	-15%
Atlanta, GA	1	I-16 Soperton to Savannah	161	194	20%
Atlanta, GA	1	Corridor Subtotal	2,013	2,104	4%
Atlanta, GA	2	I-75 Bolingbroke to Cordele	641	487	-24%
Atlanta, GA	3	I-95 Port Wentworth to Darien	415	473	14%
Atlanta, GA	1-3	Region Subtotal	3,069	3,064	0%
Pocatello, ID	4	I-15 UT State line to MT State line[1]	427	457	7%
Pocatello, ID	4	US-20 Idaho Falls to MT State line[1]	54	118	119%
Pocatello, ID	4	Corridor Subtotal	481	575	20%
Pocatello, ID	5	I-84 OR State line to Mountain Home[1]	763	530	-30%
Pocatello, ID	5	I-84 Mountain Home to UT State line[1]	817	1,003	23%
Pocatello, ID	5	I-86 Jct. I-84 to Pocatello[1]	92	174	89%
Pocatello, ID	5	Corridor Subtotal	1,672	1,707	2%
Pocatello, ID	6	I-90 WA State line to MT State line[1]	212	206	-3%
Pocatello, ID	6	US-12 Lewiston to MT State line[1]	64	83	30%
Pocatello, ID	6	Corridor Subtotal	276	289	5%
Pocatello, ID	4-6	Region Subtotal	2,429	2,571	6%
Harrisburg, PA	7	I-81 Jct. I-64 to Harrisonburg[1]	1,023	758	-26%
Harrisburg, PA	7	I-81 Harrisonburg to WV State line[1]	817	964	18%
Harrisburg, PA	7	I-81 MD State line to Harrisburg[1]	1,493	1,307	-12%
Harrisburg, PA	7	I-81 Harrisburg to Frackville[1]	618	1,005	63%
Harrisburg, PA	7	Frackville to Scranton[1]	480	574	20%
Harrisburg, PA	7	Corridor Subtotal	4,431	4,608	4%
Harrisburg, PA	8	I-80 Dubois to Rote[1]	654	511	-22%
Harrisburg, PA	8	I-80 Rote to Bloomsburg[1]	507	383	-24%
Harrisburg, PA	8	I-80 Bloomsburg to Scotrun[1]	546	222	-59%
Harrisburg, PA	8	Corridor Subtotal	1,707	1,116	-35%
Harrisburg, PA	7-8	Region Subtotal	6,138	5,724	-7%
Memphis, TN	9	I-40 North Little Rock to Brinkley	652	828	27%
Memphis, TN	9	I-40 Wheatley to Memphis	808	888	10%
Memphis, TN	9	I-40 Memphis to Brownsville	119	373	213%
Memphis, TN	9	I-40 Brownsville to Holladay	740	397	-46%
Memphis, TN	9	Corridor Subtotal	2,319	2,486	7%
Memphis, TN	10	I-55 Winona to Batesville	322	378	17%
Memphis, TN	10	I-55 Batesville to Memphis	158	249	58%
Memphis, TN	10	I-55 Memphis to Blytheville	934	686	-27%
Memphis, TN	10	I-55 Holland to Bertrand	594	536	-10%
Memphis, TN	10	Corridor Subtotal	2,008	1,849	-8%
Memphis, TN	9-10	Region Subtotal	4,327	4,335	0%
All	All	TOTAL	15,963	15,694	-2%

[1]Number of trucks counted during the peak hour in the field observational study.
[2]Estimated trucks demanding a parking space during the peak hour.
[1]Segment classified as a rural segment.

It should be noted that the demand for parking along half the 29 segments was at or exceeding capacity at the time the observational studies were conducted. Thus, for these segments, one would expect the model to estimate a demand higher than the observed number of trucks, as there were drivers that were demanding a space, but were not counted because there was no place for them to park. Because it is unknown how much demand is not being met along these corridors, it is difficult to know by how much the model should estimate demand over that which was observed. Because the model was calibrated to the observed parked trucks (rather than the actual demand for some of the segments), the use of this model will result in a conservative estimate of truck parking demand.

5.0 SUMMARY AND CONCLUSIONS

The objective of this research was to estimate the extent and geographic distribution of truck rest parking supply and demand along the National Highway System in accordance with Section 4027 of the Transportation Equity Act for the 21st Century. This report described the development, calibration, and application of the truck parking demand model used to estimate truck rest parking demand.

The parking demand model developed for this study estimates parking demand for a highway segment (defined by the analyst) rather than a single parking facility. The model incorporates a variety of factors known to affect the demand for truck parking, which include: traffic engineering factors (e.g., AADT, travel time, peak-hour factors), truck driver behaviors (e.g., time spent loading/unloading, time spent at home, time spent resting at shipper/receiver), and Federal hours-of-service regulations (e.g., a maximum of 70 hours on duty in eight days). A step-by-step method for selecting analysis segments and applying the model is presented.

About half of the model parameters where derived from survey responses from over 2,000 drivers across the United States. The other half of the model parameters were calibrated using overnight field observations of parked trucks in eight States: Arkansas, Georgia, Idaho, Mississippi, Missouri, Pennsylvania, Tennessee, and Virginia. Observational studies were performed on 29 segments of highway in these eight States representing four regions and ten corridors. By comparing model estimates to the field counts of parked trucks, two model parameters were calibrated: the long-haul peak parking factor (PPF_{LH}) and the short-haul to long-haul ratio (P_{SH}/P_{LH}).

The parking demand estimates produced by the model are highly variable at the segment level. For example, the model estimates are within ±10 percent of the observed parked trucks for only four of the 29 segments (14 percent), ±20 percent for 11 of the 29 segments (38 percent), and ±30 percent for 20 of the 29 segments (69 percent). At the corridor level, on the other hand, the model is much more accurate. Model estimates are within ±8 percent of the observed parked trucks for six of the ten corridors (60 percent) and ±20 percent for eight of the nine corridors (80 percent). The absolute errors in estimated demand at the segment, corridor, and regional level were 38, 12, and 3 percent, respectively.

The variance at the segment level can be attributed to several factors. One factor is that the model does not take into account the geographic distribution of available truck parking spaces. Although the amount of available parking does not affect the actual demand, the geographic distribution of the supply will affect where the demand is met. Therefore, when field counts were compared to model estimates, it is not surprising that, in some cases, the estimates for one segment were too low, while the estimates for the next segment were too high. Additional research into how to add a factor to the model that represents the distribution of supply would make the model more accurate at the segment level and more useful for local planning. In addition, the use of only two short-haul to long-haul ratios (i.e., .36/.64 for urban segments and .07/.93 for rural segments) may not adequately reflect the variations across regions and corridors. To better understand the variability in the short-haul to long-haul ratio, origin-destination surveys could be conducted in a variety of locations that represent a range of distances from metropolitan areas.

It should also be noted, however, that the error at the segment level does not necessarily indicate that the demand model is inaccurate when applied to highway segments, but may indicate that the lack of parking spaces on some highway segments creates unmet demand that appears in field observations as unusually high demand on nearby segments with a surplus of parking.

In conclusion, the first step in alleviating parking shortages is to identify locations where problems are likely to exist, and the demand model is a good tool for achieving this goal. Overall, the model produces acceptable estimates of parking space demand, with an error of only –2 percent for the 29 segments where parked truck counts were conducted, an estimate within 269 spaces of the observed parked trucks. Because at the time the observational studies were conducted, half of the 29 segments were at or exceeding capacity, the use of this model will result in conservative estimates of truck parking demand.

One of the most powerful features of the truck parking demand model is its ability to estimate future demand so that long-range plans can be formulated. States could use this model to identify locations with possible parking shortages, then, based on local knowledge and field observations, refine the model to better reflect local conditions. The refined model could then be used to make projections of parking demand for long-range planning purposes.

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