FINAL REPORT

ESTIMATION OF THE DEMAND FOR COMMERCIAL TRUCK PARKING ON INTERSTATE HIGHWAYS IN VIRGINIA

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ABSTRACT

The steady growth of commercial truck travel has led to an increasing demand for truck parking spaces at public rest areas and private truck stops on interstate highways in Virginia. This study developed a methodology to determine the supply and demand for commercial truck parking along these corridors. *Supply* was defined as the number of parking spaces available for commercial truck parking, and *demand* was defined as the sum of the parking accumulation and illegal parking at a given time.

Phase I of this study developed a methodology to determine the supply and demand for commercial truck parking using I-81 in Virginia as a case study. This Phase II study included other interstate highways in Virginia, checked the applicability of the parking demand model developed in Phase I, and developed new models when necessary.

Extensive data on the characteristics of commercial truck parking and the characteristics of each truck stop and rest area were collected. In addition, truck drivers and truck stop owners/operators were surveyed. The data collected were used to develop models to describe the relationship between parking accumulation and independent variables such as traffic volume on the highway, truck percentage, parking duration, and the distance from a highway to a truck stop. After the applicability of the models was tested, they were used to estimate commercial truck parking demand in 2010 and 2020. Deficiencies of parking spaces with respect to estimated demand were then determined for each truck stop and the entire Virginia interstate highway system.

The results indicate that the demand for commercial truck parking at individual truck stops on I-95 exceeds the supply by 10 to 22 percent and that there is no commercial parking shortfall at truck stops along I-64, 1-77, and I-85. However, there are shortfalls at rest areas on I-66, I-77, I-85, and I-95, varying from about 6 percent on I-85 to about 32 percent on I-95. If no new parking spaces are provided and a 5 percent increase in truck travel is assumed, the demand/supply ratio in 2010 for large truck parking on all interstate highways in Virginia will exceed 1.00. This deficiency could be as high as 40 percent on I-95.

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INTRODUCTION

The lack of adequate parking spaces for commercial trucks at rest areas and truck stops on the interstate highway system throughout the nation in recent years is a serious concern for the public and private industries using these facilities. Several studies have indicated that the inadequacy of parking facilities for commercial trucks may be associated with fatigue-related crashes involving these vehicles.[1-4] In addition, truck drivers who cannot find parking spaces at these facilities often choose to park on ramps and the roadway shoulders, which often results in accelerated deterioration of the pavement.[5-10]

Studies[11, 12] have investigated the demand for and supply of truck parking facilities; however, the results cannot be directly applied to Virginia highways without further evaluation for two reasons. First, most studies focused on rest area parking or lacked detailed information on truck stops. However, in Virginia more than 80 percent of commercial truck parking spaces are provided at truck stops owned by private organizations. Second, truck drivers are allowed a maximum stay of only 2 hours at the rest areas that comprise the public parking facilities for trucks and automobiles in Virginia.

The importance of the adequacy of places for truck drivers to stop and rest continues to increase as trucking transportation continues to grow. The hours-of-service (HOS) rules established by the Interstate Commerce Commission in 1937 and revised in 2003 limit the number of hours that truck drivers may drive and be on duty.[13] For example, these rules require that drivers have a minimum of 8 consecutive hours off duty. This creates a demand for parking spaces where truck drivers can stop and rest. The creation of the interstate highway system in 1956 led to the rapid growth of the trucking industry and, as a consequence, the construction of private truck stops and travel plazas along interstate corridors to provide such services as fuel, food, showers, and truck repair facilities, in addition to overnight parking spaces.

The Virginia Transportation Research Council (VTRC) has been conducting a three-phase study to investigate the supply and demand for truck parking facilities in Virginia since 1999. The ultimate objective of this study is to develop a real-time information system for truck drivers on interstate highways in Virginia. Phase I developed a method for estimating the supply and demand for commercial truck parking using I-81 as a case study.[14] Phase II, described in this report, estimated the commercial truck parking demand on other interstate highways in Virginia using the method developed in Phase I. Phase III will develop a real-time parking information system for commercial drivers.

PURPOSE AND SCOPE

The purpose of this study was to develop and apply a methodology for estimating the supply and demand for commercial truck parking on Virginia's interstate highways to determine the shortage, if any. Appropriate models that describe the relationship between parking accumulation and the independent variables were needed for this purpose.

All interstate highways in Virginia (except I-81) were included in this Phase II study. I-81 was excluded because it was the subject of the Phase I study.[14] Although the study was mainly concerned with the interstate highways in Virginia, data were also collected for U.S. Route 29 (US 29), one of the main primary arterial highways in Virginia. Thus the following highways were included in this phase: I-64, I-66, I-77, I-85, I-95, and US 29. In addition, 41 public rest areas and 54 private truck stops in Virginia were included. Only truck stops with 15 or more parking spaces were included.

The specific objectives of the study were:

1. to determine the supply characteristics of commercial truck parking facilities along interstate highways in Virginia

2. to determine the demand characteristics of commercial truck parking along interstate highways in Virginia

3. to determine current shortfalls in the supply of commercial truck parking spaces along interstate highways in Virginia

4. to predict demand and shortfalls for commercial truck parking spaces along interstate highways in Virginia for 2010 and 2020

5. to estimate the cost of eliminating any shortfalls.

METHODOLOGY

The following tasks were conducted to achieve the study objectives:

1. literature review

2. data collection
3. data analysis
4. model testing, development, and selection
5. parking demand estimation
6. demand and supply comparison
7. cost estimation for eliminating any shortfalls.

Literature Review

A detailed literature search on the relevant topics was carried out using the Transportation Research Information Service (TRIS), the VTRC library, and the University of Virginia libraries. In addition, an investigation of current practices for estimating parking demand at rest areas and truck stops was conducted. For current issues related to commercial parking spaces availability, an Internet search was conducted. The results of the literature review are summarized under the following topics:

1. previous studies related to commercial truck parking

2. the relationship between motor carrier safety and the inadequacy of commercial truck parking spaces

3. existing methods/models for commercial truck parking demand and estimation

4. time restriction on parking spaces in different states at rest areas.

Previous Studies Related to Commercial Truck Parking

Perfater[15] conducted a survey in an examination of motorist usage and operation of Virginia's rest areas and welcome centers. When asked why they would choose to stop at a rest facility rather than exit the interstate, 69 percent of the respondents stated that rest areas were more convenient and saved time. The number of commercial truck drivers surveyed was not documented.

In 1992, the U.S. Senate recommended further research on the causes of truck drivers' loss of alertness at the wheel, including an evaluation of the adequacy of public and private places for truck drivers to stop and rest. In 1996, this nationwide study,[11] conducted by the Trucking Research Institute, Apogee Research, and Wilbur Smith Associates, assessed the supply and demand for long-term truck parking at the statewide level. This study estimated a shortfall of 28,400 public truck parking spaces nationwide and a shortfall of 1,322 truck parking spaces for rest areas in Virginia based on their model. One disadvantage of the study was that it did not explicitly identify the road sections with shortfalls and did not estimate future shortfalls for different corridors. In addition, the researchers suggested that some of the shortfall at public rest areas might be satisfied by private expansion efforts. However, they gave no conclusive evidence that private truck stops and public rest areas could be directly substituted for each other.

In 1998, Section 4027 of the Transportation Equity Act for the 21st Century (TEA-21) required "the Secretary of Transportation to 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 survey results of that study indicated truck drivers considered available truck parking inadequate.[16] The analysis of the survey revealed that drivers preferred commercial truck stops and travel plazas for most activities and long-term rest, but they preferred public rest areas for parking when stopping for a short period. The growth rate of demand for truck parking was estimated to be 2.7 percent annually, the growth rate of public parking spaces was estimated to be 1 percent annually, and the growth rate for private parking spaces was estimated to be 6.5 percent annually. Truck parking space usage was also calculated for each state. A demand/supply ratio of 2.16 was obtained for public rest areas in Virginia, which was categorized as "shortage." The demand/supply ratio of private truck stops in Virginia was 0.8, which was categorized as "surplus." The total demand/supply ratio in Virginia was 0.93, which was categorized as "sufficient."[16] The drawback of this report was that it did not indicate the specific locations of the shortfalls or estimate future demands for different corridors.

The Federal Highway Administration (FHWA) hosted a Rest Area Forum in Atlanta, Georgia, in 1999.[17] The participants included 70 department of transportation (DOT) and enforcement officials, representatives of the motor carrier industry, commercial truck stop operators, commercial truck drivers, safety advocates, and other interested parties. Several highest-priority recommendations related to commercial vehicle parking were listed in the final publication. During this forum, the importance of private truck stops and travel plazas for commercial vehicle parking along the National Highway System was emphasized. To encourage private enterprise, the groups suggested providing low-interest loans, public/private partnerships, and tax incentives and using local law enforcement to respond to crime reports at private truck stops.

Safety and Parking

The lack of truck parking has been perceived as a safety problem for a number of years. Research by Wang et al.[18] for the National Highway Traffic Safety Administration suggested that truck driver fatigue could be a contributing factor in as many as 40 percent of all truck crashes. Thirty-one percent of all fatal crashes involving truck drivers was suspected to be fatigue related by the National Transportation Safety Board (NTSB) study[19] in 1990. The 1995 NTSB study also revealed that two of the most important causal factors of a fatigue-related crash are the duration of the last sleep period and the time slept in the past 24 hours. A 7-year study on commercial motor vehicle driver fatigue and alertness by FHWA also indicated that the quantity and quality of sleep obtained by the subjects in their principal sleep periods were low.[2] The quantity and quality of sleep was listed as the third factor influencing driver fatigue and alertness after time of day of driving and duration of driving.[1] The inadequacy of parking for commercial drivers probably has an impact on all of these factors.

Truck drivers often unsafely park their trucks on the shoulders of roadways and on entrance and exit ramps at interchanges when they reach the federal HOS limit and are unable to locate suitable parking spaces. Illegal parking on the shoulders of the entrance and exit ramps is hazardous for three reasons. First, the speed of the trucks as they re-renter the through lanes of the freeway from the shoulders may be significantly lower than the speed of traffic on the through lanes because of a short acceleration distance. Second, it creates a problem for vehicles decelerating onto or accelerating from ramps. Third, it creates an additional fixed object if drivers run off the road. For example, in 1999, a crash in Jackson, Tennessee, involving four truck tractor-semi-trailers resulted in the death of two occupants of the vehicles and serious injury to another.[1] Three of the four trucks were parked on the shoulders of the acceleration lane because the closest rest areas were full. Studies by Cheeseman and Voss in South Dakota and Agent and Pigman in Kentucky have shown that the risk of fatal crashes involving vehicles on shoulders is statistically significant.[8, 9]

The Phase I study on I-81 also found an average of six commercial trucks illegally parked on the ramps and access roads adjacent to some parking facilities. The reason frequently given by truck drivers for parking illegally was either "not finding available legal parking spaces" or "not knowing where parking would be available."[14]

Methods/Models on Parking Demand Estimation

The literature offers several methodologies for estimating parking demand. This includes the Institute of Transportation Engineers' (ITE) parking generation rates, regression equations, and cumulative distributions that are widely used in urban areas.[20] Unfortunately, the ITE rates did not cover commercial vehicle parking along major highways. In order to develop statewide rest area plans, the FHWA and several state DOTs also developed prediction models to determine the number of parking spaces required at rest areas. These models fall into two board categories: macro-level models and micro-level models.

Macro-level Models

The Transportation & Mobility Planning Division of the Virginia Department of Transportation (VDOT) reviewed and updated a macroscopic corridor-level parking demand model for rest areas that was originally developed by the Minnesota DOT (MnDOT) and was based on data collected in Minnesota. The updated VDOT model, shown in equation 1, increased the percentage of mainline traffic entering the rest area from 12 to 14 percent and decreased the design hour usage ratio from 0.15 to 0.10 if the ADT exceeded 12,500 vehicles as shown in Table 1.[21] The American Association of State Highway and Transportation Officials (AASHTO) recommended this model for use in estimating required truck parking spaces in developing plans for statewide rest areas.[21]

$$NTSPACES = \frac{ADT \times P \times DH \times D_t \times PF}{VHS} \qquad \text{[Eq. 1]}$$

where

NTSPACES = number of truck parking spaces required

ADT = average daily traffic with access to rest area

P = total percentage of mainline traffic stopping at rest area

DH = design hour usage; design hour compares the design hourly volume, usually the 30th to 50th highest hourly volume, to the annual ADT, producing a factor that predicts a peak usage average-hour situation

D_t = percentage of truck parking spaces

PF = peak factor; this is the ratio of average day of 5 summer months to average day of year

VHS = number of vehicles parked per hour per space.

The MnDOT/VDOT model considers only the impact of traffic flow along the mainline to estimate the truck parking demand. Many other non-traffic factors that may affect the demand, such as location, food facilities, lighting, and parking spaces available at nearby truck stops, are not considered. Apogee, Inc., developed a more complicated model based on the MnDOT/VDOT model to address the impact of non-traffic factors on truck parking demand at rest areas. The formula for the demand model is the same as that given in Equation 1. However, the Apogee model allows for varying the values of the parameters for the percentage of mainline traffic stopping at rest areas (P) and the design hour usage (DH) depending on a set of decision rules. These decision rules are related to the factors listed in Table 2.[11] The decision rule for P allows for the increase of the default value (0.12) by 0.01 for each variable that was coded as "1" in Table 2. The decision rule for DH is based on different ADT levels. For ADT of 12,500 and less, DH = 0.15. For ADT greater than 12,500 and less than 30,000, DH = 0.10. For ADT of 30,000 and higher, DH = 0.0075. The recommended value for vehicles per hour per parking space (VHS) is 2.0 instead of 3.0.

Although the Apogee model considered many non-traffic factors, it did not address the impact of parking spaces at private truck stops on rest area parking needs or the different peak periods for cars and trucks. That model also did not address the impact of time restrictions on parking at rest areas.

Table 1. Parameters of Corridor-Level Parking Demand Model for Rest Areas

Parameter	% Mainline Traffic Entering Rest Area (P)	Design Hour Usage (DH)	Distribution Between Car and Truck Parking (D_t)	Peak Factor (PF)	Vehicles per Hour per Parking Space (VHS)
VDOT values	General, P = 0.12 Welcome center, P = 0.14	ADT < 12,500 DH = 0.15; ADT > 12,500 DH = 0.10	0.25	1.80	3.0

Source: Guide for Development of Rest Areas on Major Arterials and Freeways (Ref. 21).

Table 2. Recommended Parameter Values

Factor	Data Coding
One-way average daily traffic	Enter data as collected.
Distance from the previous rest area	If distance from previous rest area exceeds 50 miles, code as “1,” if not, code as “0.”
Welcome center	If welcome center, code as “1,” if not, code as “0.”
Type of truck parking spaces at rest area	If spaces are diagonal pull-through type, code as “1,” if not, code as “0.”
Rest area food facilities	If food facilities available, code as “1,” if not, code as “0.”
Rest area lighting	If lighting is considered adequate, code as “1,” if not, code as “0.”
Availability of rest area attendant	If attendant is available, code as “1,” if not, code as “0.”
Parking spaces at private truck stops	Enter data as collected.

Source: Commercial Drivers Rest Area Requirements (Ref. 11).

Micro-level Models

The Ohio DOT developed a Lotus 1-2-3 spreadsheet that used the variation of traffic volume with time and the parking duration distribution tables to develop a daily accumulation of trucks, listed by half-hour periods, for a given rest area.[12] Three traffic levels could be used in the spreadsheet depending on the information available: one-way ADT only, one-way ADT and overall percentage of trucks, and one-way volume of total traffic and volume of trucks from each 24 one-hour periods. The factors considered in the spreadsheet included truck parking duration, location of the rest areas, and traffic variations (total vehicles on mainline in each hour, truck percentages on mainline, and percentages of truck that entered the rest areas). The spreadsheet yielded results that were similar to those obtained from observations.

Parking Time Restriction

Virginia state law restricts parking by cars and trucks to a maximum of 2 hours in a rest area. Virginia is one of many states with such a law. The results of a 1999 survey show that 18 states have laws restricting the time a vehicle can park in a public rest area.[18] All east coast states except Maryland, North Carolina, and all of the New England states restrict the time.[1]

VDOT’s opinion is that public rest areas were designed for brief stops and not for overnight parking. A 2-hour parking restriction provides a majority of motorists arriving at the rest area a higher probability of finding somewhere to park. VDOT also stated that it had no plans to change the 2-hour restriction at public rest areas.[17]

Several studies indicated that truck drivers preferred public rest areas for short breaks and private truck stops for extended parking.[11, 12, 14] When truck drivers are tired or out of the HOS time to drive, they need to leave the roadway as quickly as possible. However, the stopover is not always possible because of a lack of information on the location of parking facilities or the unavailability of parking spaces. These researchers also indicated that time restrictions for parking were incompatible with the federal HOS regulations and can encourage drivers to continue driving while fatigued.[1-4]

Summary of Literature Review

The literature review showed that the lack of adequate parking spaces for commercial trucks at rest areas and truck stops is a serious problem throughout the United States. Study results have also indicated that the inadequacy of parking facilities for commercial trucks may be associated with fatigue-related crashes involving these vehicles. The literature review also revealed that some interstate highways in Virginia have a shortage of commercial truck parking spaces during late evening and early morning hours. Although the literature review identified many studies of truck parking demand along interstate highways, most studies focused on rest areas. Even those studies that focused on truck stops did not have detailed information on truck stops in Virginia. Further, most of the studies did not consider peak nighttime commercial parking demand. Another shortcoming of the studies is that they did not identify the specific locations of the shortfalls or estimate the future shortfalls for different corridors.

Data Collection

To evaluate the adequacy of parking spaces for commercial trucks along interstate highways in Virginia, information on available parking spaces and parking demand for commercial trucks was necessary. Some of this information was available, and other necessary information was not. Examples of available information are number of public rest areas, their locations, and number of parking spaces. Examples of unavailable information are number of parking spaces for commercial trucks at individual private truck stops adjacent to the interstate highways, average duration for different times of the day, and other characteristics of commercial truck parking demands. Results obtained during the Phase I study[14] identified discrepancies between the numbers of parking spaces actually counted and those documented for many truck stops. Although two models were developed for relating parking accumulation and other independent variables for the truck stops along I-81, there was no guarantee that the models would adequately describe parking accumulation at truck stops on other interstate highways in Virginia. It was therefore necessary to test the existing models for their suitability at different truck stops and if necessary to develop new models for these truck stops. To carry this out, adequate data on accumulation and duration were needed, which required extensive data collection on these characteristics.

Data were collected between July 2001 and November 2002. The data collection consisted of the following tasks:

1. identification and inventory of commercial truck parking facilities
2. observation of commercial truck parking characteristics
3. acquisition of mainline traffic data
4. determination of illegal parking
5. surveys of truck drivers and truck stop owners/operators.

Identification and Inventory of Commercial Truck Parking Facilities

The research team identified rest area locations and number of parking spaces by consulting with VDOT personnel. Rest areas in Virginia are operated 24 hours a day and are located adjacent to the interstate highways. Most of the rest areas provide parking spaces for passenger cars, commercial trucks, buses, and leisure vehicles. Rest areas are operated free of charge to the public but have a 2-hour parking restriction. Amenities at most rest areas include rest rooms, vending machines, telephones, picnic areas, and pet rest areas. Truck stop locations were identified by two methods. First, reference documents that listed the locations and amenities of truck stops were consulted.[22, 23] Second, members of the research team drove along each interstate highway in the study, exited at each interchange, and drove at least 2 miles in each direction from the interchange to identify additional truck stops that were not listed in the reference documents. Truck stops are privately owned by both individuals and national or regional franchises. The majority of truck stops that serve interstate highways are located within 2 miles of an interchange on the interstate, and most operate 24 hours a day, 7 days a week. Service is usually provided for all vehicle types, although emphasis is placed on services for commercial vehicle drivers. In general, the variety of services depends on the size of the truck stop.

Thirty-four counties and independent cities in the study corridors have parking facilities for commercial trucks. Twenty-seven of the 41 rest areas and 25 of the 53 truck stops were included in this Phase II study. The other rest areas and truck stops were investigated in the Phase I study.[14] Each rest area or truck stop with 15 or more parking spaces for commercial trucks and located within 2 miles from the mainlines was identified. Each site was visited, and its location was recorded using global positioning system (GPS) equipment and recorded on a geographic information system (GIS) map of Virginia. The detailed location information of each facility was measured from the GIS map in the laboratory, e.g., distance of the nearest upstream interchange, distance of the nearest downstream truck stop or rest area, and distance of the nearest upstream truck stop or rest area. In addition, during the inventory visit to each site, the following characteristics were recorded:

- number of truck parking spaces available at each site
- type of truck parking space layout
- time of operation and limit on duration of parking, if any
- type of ownership (private or public)
- availability and type of food services
- availability and type of entertainment
- availability of other types of facilities (e.g., telephones, restrooms, lighting).

Observation of Commercial Truck Parking Characteristics

Each location for which permission was obtained from the owner/operator was visited a second time to collect data on the associated parking characteristics including parking accumulation and duration. Some of the truck stops were visited a third time to obtain the maximum truck parking accumulation. In this study, *parking accumulation* was the number of parked trucks in a specific location(s) at a specified time, and *parking duration* was the time a truck was parked in a specific parking slot.[24] The license plate method (recording the last three digits of the license plate) was used to collect data on parking accumulation and duration at the truck stops and rest areas.

Initially, the data were collected every 30 minutes, from 2 P.M. to 10 P.M. Table 3 shows an example of the typical forms used to collect the data for this study. Data on each selected site were collected on one typical weekday (Tuesday, Wednesday, or Thursday). The observed data were processed in the transportation laboratory at the University of Virginia to obtain the number of trucks parked by time of day, number of trucks parked in designated spaces, number parked in other spaces, and time each truck remained parked.

However, one unexpected problem was found. Contrary to what was found on I-81 in the Phase I study,[14] the maximum parking accumulation at several truck stops and rest areas did not occur by 10:00 P.M. Because of this, a supplementary survey was conducted at these truck stops and rest areas between 11:30 P.M. and 3:00 A.M. to obtain the maximum truck parking accumulation at these locations.

Table 3. Survey Form for Parking Accumulation and Duration and Sample Data

Location: I-64 Zion Crossroads		**Direction: Eastbound Exit 136**		**Date: August 1, Wed.**		**Prepared by Kate/Omar**
Space No.	**Time**					
	2:00 (last 3 digits of license)	**2:30 (last 3 digits of license)**	**…**	**9:00 (last 3 digits of license)**	**9:30 (last 3 digits of license)**	**10:00 (last 3 digits of license)**
1	018	018			556	556
2	101	101	101	101		934
3	502	420	420	126	126	126
4	413	413	413	413	480	480
5*	Ken	Ken	Ken		824	824
6*				349	349	349
* = Unmarked.						

Acquisition of Mainline Traffic Data

An Ethernet website managed by VDOT's Mobility Management Division provides detailed traffic counts information.[25] The division is managing the operation of 250 continuous count stations, including collecting, processing, reviewing, and analyzing the traffic count data and publishing and distributing related publications. The website also provides traffic information for thousands of non-continuous count stations. Figure 1 shows the interface of traffic counts query for I-95 NB Exit 89 (from MP 86.64 to MP 89.31), where there is a truck stop. The researchers could obtain detailed hourly traffic counts on the time of day when they did the parking accumulation and duration survey. The continuous traffic counts included vehicle classification and lane distribution of the traffic flow. Another important data element for the mainline traffic was the growth rates of different sections along the highway corridors. For the Phase I study,[14] the traffic growth rates were obtained from VDOT's Transportation &

Figure 1. Interface of Traffic Counts Query

Mobility Planning Division. This was because of the I-81 traffic improvement project that included their estimation of the traffic growth rates at different sections of I-81. However, the division could not provide enough traffic growth rates for the highways included in this Phase II project.

The research team obtained an Excel file from the Transportation & Mobility Planning Division that was used to predict traffic volumes based on historical data. This was a linear regression model template, which was used to calculate all the traffic volume predictions for 2010 and 2020.

Determination of Illegal Parking

Since the main objective for obtaining data on illegal parking in this study was to estimate the excess demand over the supply of parking spaces, the data on illegal parking were collected during the periods of peak accumulation at the truck stops and rest areas. Members of the research team drove along the adjacent highways during the peak accumulation period and recorded the number of vehicles illegally parked on the shoulders of the highways and at the entrance and exit ramps of interchanges adjacent to each truck stop. The number of illegally parked trucks (trucks parked at unmarked areas) within each parking facility was also recorded.

Surveys of Truck Drivers and Truck Stop Owners/Operators

The researchers experienced difficulties in obtaining permission from truck stop owners/operators to conduct the survey. Permission was obtained for only 12 sites, and researchers were restricted to leaving the questionnaire surveys for the truck drivers without any face-to-face interviews. The questionnaire surveys were therefore administered to truck drivers at truck stops for which permission was obtained. The questionnaires together with stamped addressed envelopes were left at these truck stops. The researcher told some of the drivers that there were survey forms from VDOT and encouraged them to complete and return the forms. The researchers also asked the truck drivers to pass the word around. The drivers then completed the questionnaires and sent them back to the researchers. Although the researchers tried to contact several trucking associations and individual truck companies, there was no response from them. Therefore, no questionnaires were sent to them.

Information obtained from truck drivers included frequency of use, factors that influenced their selection of a particular truck stop, adequacy of existing parking facilities, and where they would park if there were no parking spaces at the rest areas and truck stops of their choice. Space was also provided for the truck drivers to record any comments they wished to convey to the researchers. The results of the driver survey in Phase II were compared with those of Phase I.[14]

Truck stop owner/operator survey forms were left at individual truck stops, and the owners/operators were asked to return them by mail to VTRC. Information obtained from the truck stop owners/operators included the day of the week and time of day that maximum accumulation occurred, types of services provided, and adequacy of the existing parking facilities for commercial trucks.

No questionnaires were distributed in rest areas, as extensive data were collected at the rest areas during the Phase I study and these data were not used for developing any models.

Data Analysis

The data on accumulation collected at each area were used to determine the variation of truck parking demand with time of day and the effect of truck traffic on the demand for parking. The data on parking duration were used to examine the time trucks remained at a given site and to what extent this time was influenced by the characteristics of the site. Intervals of one-half-hour were used. The information obtained from the survey of truck stop operators and drivers was also summarized to determine the specific times of a typical day truck parking facilities were full or overflowing.

Model Testing, Development, and Selection

Model Testing

The Phase I study provided regression models on truck parking demand, which were based on parking information along I-81 in Virginia.[14] The research team was not confident that the models developed in the Phase I study could be directly applied to other interstate highways. The models were therefore first tested for their applicability to each truck stop using the data on the corresponding dependent and independent variables collected in this Phase II study. The Chi-squared (χ^2) test at a 5 percent significance level was used for this analysis. In cases when the models of the Phase I study could not fit the field data of this Phase II study, new models relating the accumulation as the dependent variable with identified independent variables were developed.

Stepwise regression analysis was used to identify significant independent variables in the Phase I study.[14] Based on that experience, multiple linear regression analysis was used to develop new models in Phase II, using the independent variables identified in Phase I. However, a correlation analysis was also conducted to test whether there was any correlation between two or more of these independent variables, using the data collected in this Phase II study. Variables that did not highly correlate with each other were finally used in the development of the models. The criterion was that the Pearson correlation factor between any two independent variables used in the models should be less than 0.65. It was anticipated that the independent variables that would be used in the demand model would include the following:

- *TotalTruck:* total number of trucks at mainline near a truck stop in half hour intervals
- *DailyTruck:* total number of trucks at mainline near a truck stop in a day
- *PercentTruck:* percent of trucks in the traffic stream in half hour intervals
- *Duration:* duration at a truck stop in half hour intervals
- *Dist_mainline:* distance from a truck stop to mainline
- *Dist_TS:* distance from a truck stop to the nearest truck stop
- *Dist_RA:* distance from a truck stop to nearest rest area
- *SERVICE:* dummy variable for measuring the difference of services between large and small truck stops (number of spaces greater than/equal to 60, SERVICE = 1; number of spaces less than 60, SERVICE = 0).

The services provided depended largely on the size of the truck stops. Truck stops with 60 or more parking spaces usually provide full services that include restaurants, TV lounge areas, shower stalls, laundromats, game rooms, truck washes, truck repairs, and sleeping facilities. In general, truck stops with fewer than 60 parking spaces do not provide full services.

Model Development

In Phase I,[14] the models were developed using all of the data collected except those at two sites that were later used to test the accuracy of the models. Model 1 was based on the assumption that truck drivers arriving at a truck stop between 8 P.M. and 9 P.M. would stay for an average of 5 hours and truck drivers arriving at a truck stop after 9 P.M. would stay for an average of 6 hours. Model 2 was based on the assumption that truck drivers arriving after 9 P.M. would stay until 5 A.M. the next day. These assumptions were based on the information obtained from truck stop owners/managers. The results from these two assumptions were not significantly different. In this report, a similar assumption was made.

Model Selection

Accuracy and complexity were the major considerations given in selecting the best model. The goal for selecting the best model was to select the model with the best fit and the least complexity. There are at least two ways to consider the accuracy and complexity of the developed models.[26]

1. *Reserve data.* Split the available data into two subsets; train the candidate models on the first set; and use the second set to choose the best model. It should be noted that excessive training sometimes tends to give complex models that may predict new points poorly.

2. *Penalize complexity*. This method measures the model complexity by the number of parameters, K, and, using all data, chooses the model that is best according to a function of K, the training error.

In this study, the reserve data option was used to check the accuracy of the models, which was consistent with the method used in the Phase I study.[14] The Chi-squared test at a 5 percent significance level was also used for this analysis.

Parking Demand Estimation and Demand and Supply Comparison

The appropriate model was applied to the projected traffic and truck volumes for 2010 and 2020 and the maximum parking accumulation obtained for these years. It was assumed that the distributions of parking duration in 2010 and 2020 would be the same as those currently observed but that the accumulations would be different. The increasing rates of the maximum accumulation in a corridor were then applied to commercial truck parking at the rest areas in that corridor. The total parking demand was then determined as the sum of the estimated maximum accumulation at the truck stops and the estimated truck parking demand at the rest areas.

The difference between future demand and supply was defined as the shortage. A sensitivity test was also conducted to determine the impact of increased supply on the shortfall by assuming that parking spaces will increase at varying annual rates.

To compare the overall supply and demand for parking on the highways, each route was divided into segments of homogeneous parking segments. The major factor used to divide the road into segments was the percentage of trucks in the traffic stream from the VDOT traffic counts publication.[27] The criterion used was that each segment was selected so that the truck percentage in the traffic stream of each link did not vary by more than 10 percent of that for each of the other links within the segment. The start and end locations of each segment were at interchanges. The current deficiency in parking spaces was determined as the difference between the estimated demand and the number of truck parking spaces available for each road segment.

Cost Estimation for Eliminating Shortfalls

Although many factors affect the expansion and new construction of parking spaces along major highways, such as zoning restrictions and environmental considerations, the cost of eliminating the shortfalls of commercial truck parking is a key issue for decision makers. Unfortunately, in this phase of the study, no additional information was available regarding the cost of the recent construction of commercial truck parking facilities along the corridors. Therefore, a low-high cost analysis was used. According to information derived from a study conducted by the Trucking Research Institute for new construction of commercial truck parking spaces (number of spaces greater than 50), the low average cost per space was about $30,000 and the high average cost per space was about $35,000.[11] Other cost information was obtained from a real project built by Vesuvius, Inc., in which the cost per parking space was estimated as $86,250 (including cost of land, evacuation cost, cost of gravel base and paving, and cost of lights and curbing).[28] Based on the deficiencies obtained for each highway section, the minimum ($30,000) and maximum ($86,250) costs per parking space were used to estimate the range of costs for providing the additional parking spaces to meet the future demands.

RESULTS

The results of the commercial truck parking supply and demand analysis are provided in the following sections:

- parking supply characteristics
- parking demand characteristics
- estimation of illegal parking
- estimation of current parking deficiency
- survey results
- model testing and development
- estimation of future parking demand
- estimation of future parking deficiency
- estimation of costs to eliminate shortfall.

Parking Supply Characteristics

Table 4 shows the number of commercial truck parking spaces available at each public rest area and private truck stop in each county along the interstate highways in Virginia. Thirty-four counties and independent cities in the study corridors have parking facilities for commercial

Table 4. Rest Areas and Truck Stops in Every County or City in Virginia

County	Rest Areas		Truck Stops	
	No.	Truck Parking Spaces	No.	Truck Parking Spaces
Phase I (I-81)				
Augusta	2	28	2	117
Botetourt	1	10	2	134
Frederick	1	12	1	143
Montgomery	3	52	2	55
Pulaski	-	-	2	115
Rockbridge	1	10	6	644
Rockingham	2	37	1	69
Shenandoah	-	-	4	376
Smyth	1	8	2?	55?
Washington	2	110	1	35
Wythe	1	0	6	628
Subtotal	14	267	29	2371
Phase II				
Albemarle	2	33	-	-
Alleghany	2	16	-	-
Bland	2	44	1	15
Brunswick	2	26	1	25
Campbell	-	-	1	15
Caroline	2	60	4	581
Carroll	1	19	2	100
Chesapeake	-	-	1	74
Dinwiddie	2	35	2	59
Fauquier	-	-	1	50
Goochland	2	20	-	-
Greene	-	-	1	35
Greensville	1	0	2	185
Hanover	-	-	3	484
Louisa	-	-	1	44
Mecklenburg	1	25	1	85
New Kent	2 (1-closed)	59	-	-
Prince George	1	40	-	-
Prince William	6	142	-	-
Spotsylvania	1	21	1	23
Stafford	-	-	1	207
Sussex	-	-	1	90
Virginia Beach	-	-	1	205
Subtotal	27	540	25	2277
Total	**41**	**807**	**54**	**4648**

trucks. Twenty-seven of the 41 rest areas and 25 of the 53 truck stops were included in this Phase II study. The other rest areas and truck stops were investigated in the Phase I study.[14] Tables 5 and 6 give the name, location, and number of parking spaces for commercial trucks at each rest area and truck stop. Figure 2 shows the locations of the rest areas and truck stops in each county based on the GPS data. Figure 3 gives the clustered columns for the parking spaces at truck stops and rest areas along the highways in this study.

Table 5. Rest Areas Along Interstate Highways in Virginia

No.	Route	Name	Direction	Milepost	Car Spaces	Truck Spaces	Longitude	Latitude
1	I-64	Jerry's Run*[C]	EB	2	37	0	80 11 20.54	37 48 37.49
2	I-64	Longdale Furnace[T]	EB	13	0	16	79 42 45.25	37 47 48.74
3	I-64	Charlottesville East	EB	105	68	19	78 45 51.39	38 02 43.12
4	I-64	Charlottesville West	WB	113	89	14	78 37 44.25	38 02 05.04
5	I-64	Goochland West	WB	168	26	11	77 45 46.89	37 42 19.63
6	I-64	Goochland East	EB	169	26	9	77 44 57.18	37 42 00.42
7	I-64	New Kent East	EB	213	91	34	77 02 36.80	37 29 49.53
8	I-64	New Kent West	WB	213	100	25	77 02 36.63	37 29 56.10
9	I-66	Manassas East	EB	48	16	10	77 29 39.57	38 48 29.04
10	I-66	Manassas*	WB	48	17	11	77 29 38.46	38 48 32.79
11	I-77	Lambsburg*	NB	1	70	19	80 44 49.58	36 33 33.85
12	I-77	Rocky Gap North	NB	59	90	20	81 07 45.10	37 11 07.57
13	I-77	Rocky Gap*	SB	61	60	24	81 06 15.81	37 12 22.39
14	I-85	Bracey*	NB	1	96	25	78 10 47.78	36 33 11.71
15	I-85	Alberta North	NB	32	78	13	77 50 18.77	36 51 46.54
16	I-85	Alberta South	SB	32	74	13	77 50 11.79	36 51 57.94
17	I-85	Dinwiddie North	NB	55	66	15	77 29 55.40	37 06 00.97
18	I-85	Dinwiddie South	SB	55	62	20	77 29 56.07	37 06 13.14
19	I-95	Skippers*[C]	NB	1	60	0	77 34 34.28	36 32 42.86
20	I-95	Carson	NB	37	106	40	77 23 29.65	37 00 40.26
21	I-95	Ladysmith North	NB	107	100	40	77 29 31.55	37 58 37.71
22	I-95	Ladysmith South	SB	107	36	20	77 29 34.65	37 59 04.73
23	I-95	Fredericksburg*	SB	131	56	21	77 24 46.82	38 28 09.61
24	I-95	Dale City North[T]	NB	154	0	60	77 18 44.83	38 36 01.04
25	I-95	Dale City South[T]	SB	154	0	61	77 19 05.70	38 35 30.87
26	I-95	Dale City North[C]	NB	155	78	0	77 18 42.85	38 36 08.24
27	I-95	Dale City South[C]	SB	155	111	0	77 18 59.40	38 35 41.67

* = Welcome Center; [C] = Car only; [T] = Truck Only.

The parking supply pattern for commercial trucks showed that the private truck stops play a major role in the provision of parking facilities for commercial vehicles in Virginia. In this Phase II study, about 80 percent of the commercial truck parking spaces were provided by private truck stops and about 20 percent were provided at public rest areas. To compare the overall supply and demand for parking on the highways later in this Phase II study, each route was divided into segments of homogeneous parking segments based on the percentage of truck traffic on each route. The criterion used was that the percentage of trucks in the traffic stream on any segment was not more than 10 percent different from that on any other link within the segment. Because truck percentages along I-95 varied much more than on other roadways in this Phase II study, the researchers divided I-95 so as to obtain the least variation of truck percentages within any segment while obtaining the longest length. Table 7 shows the different segments used.

Table 6. Truck Stops Along Interstate Highways in Virginia

No	Route	Name	Direction	Exit #	Truck Spaces	Longitude	Latitude
1	US 29	Quarles	NB		50	77 48 01.57	38 37 50.28
2	US 29	Shell	SB		35	78 22 25.32	38 13 45.23
3	I-64	Zion Crossroads (Citgo)	EB	136	44	78 12 59.93	37 58 24.05
4	I-64	Big Charlie's Truck Stop	NB	282	205	76 11 11.06	36 52 59.64
5	I-77	Chevron	NB	14	59	80 46 29.83	36 44 38.40
6	I-77	Exxon	SB	8	41	80 42 46.64	36 40 25.04
7	I-77	Citgo	SB	58	15	81 08 27.23	37 10 41.50
8	I664	Frank's Trucking Center	EB		74	76 25 10.27	36 47 03.08
9	I-85	Simmons Bracey Travel Center	NB	4	85	78 09 10.14	36 35 57.20
10	I-85	Circle D Mart (Chevron)	SB	39	25	77 44 06.29	36 56 26.60
11	I-85	Mapco Express (East Coast)	NB	61	34	77 29 13.17	37 11 01.98
12	I-85	Thrift Mart (Exxon)	SB	63	25	77 27 59.77	37 11 50.18
13	I-95	Simmons Travel Center	SB	8	55	77 33 25.35	36 39 38.23
14	I-95	Sadler Travel Plaza (Shell)	SB	11	130	77 33 11.84	36 42 16.67
15	I-95	Davis Truck Plaza (Chevron/Exxon)	NB	33	90	77 23 38.89	36 58 33.97
16	I-95	Richmond Travel American Center (TA)	NB	89	135	77 26 52.06	37 43 30.64
17	I-95	Ashland Travel American Center (TA)	SB	92	134	77 27 48.93	37 45 40.03
18	I-95	Doswell All American Travel Plaza	NB	98	215	77 27 01.69	37 50 49.78
20	I-95	Flying J Travel Plaza	SB	104	239	77 28 27.86	37 55 58.80
21	I-95	Pilot Travel Center #291	NB	104	55	77 27 56.13	37 56 16.02
22	I-95	Mr. Fuel #2	NB	104	20	77 28 01.24	37 56 23.24
23	I-95	Petro Shopping Center #56	NB	104	267	77 28 04.31	37 56 21.86
24	I-95	RaceTrac Fuel Stop	SB	126	23	77 30 07.39	38 14 00.76
25	I-95	Servicetown Travel Plaza	NB	133	207	77 29 33.42	38 20 39.55

Table 7. Divided Segments along Interstate Highways in Virginia

Section	Begin Milepost	End Milepost	Length (Mile)	Range of Truck Percentage (%)	Range of ADT (2001)
I-64					
1	0	56	56	29-30	3700-10000
2	87	124	37	14-15	15000-20000
3	124	177	53	14	13000-23000
4	200	275	75	6-7	18000-30000
5	275	298	23	9	27000-72000
I-66					
1	0	23	23	19-20	9700-16000
2	23	64	41	1-9	16000-97000
I-77					
1	0	32	32	29-30	14000-21000
2	40	66	26	25-26	13000-14000
I-85					
1	0	34	34	26-27	6900-11000
2	34	65(I-95)	31	20-22	9600-26000
I-95					
1	0	37	37	23-26	8700-20000
2	37	65(VA 10)	28	10-19	14000-61000
3	83	133	50	16-19	34000-69000
4	133	170	37	10-12	49000-111000

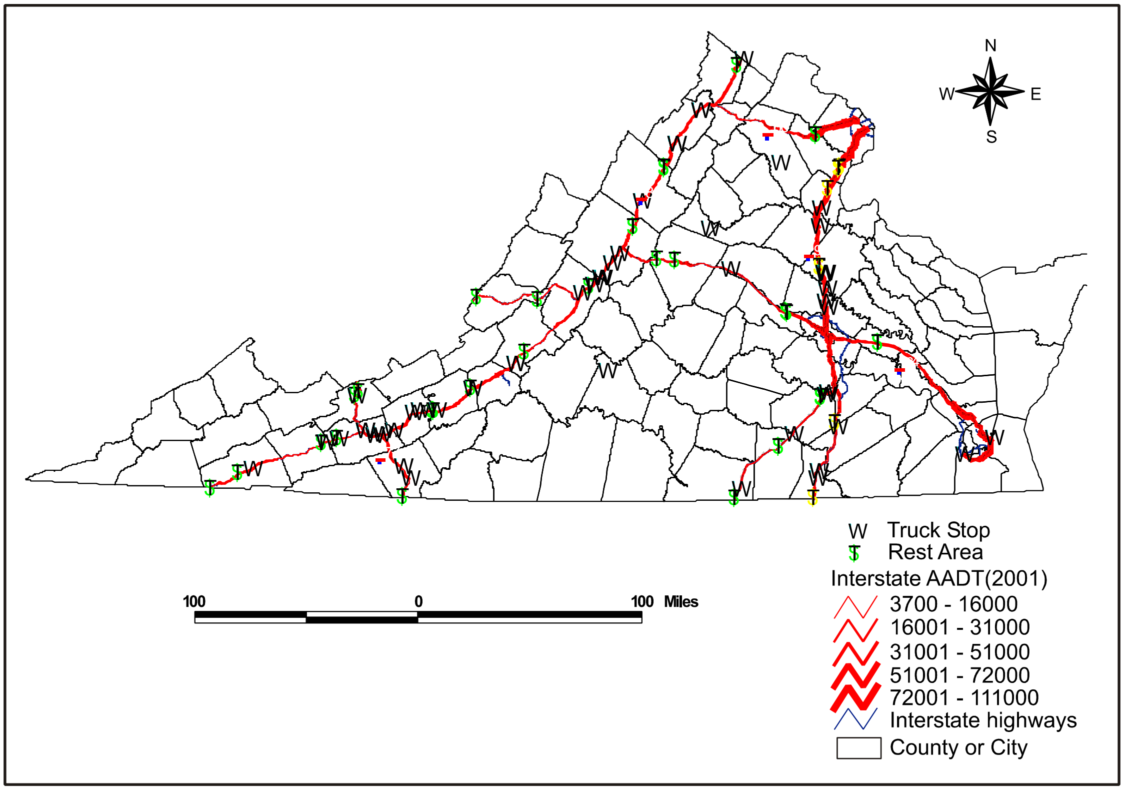

Figure 2. Locations of Truck Stops and Rest Areas in Virginia

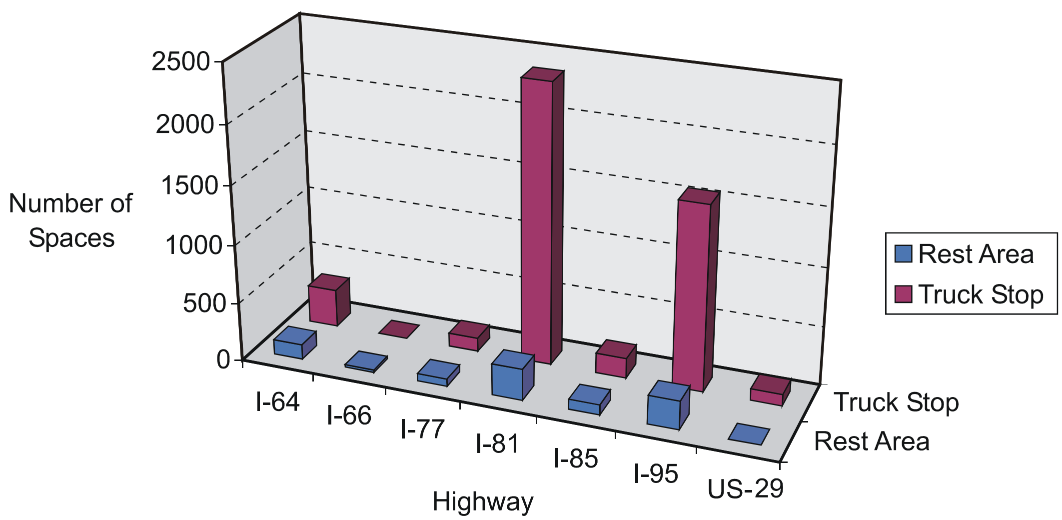

Figure 3. Commercial Truck Parking Spaces Along Selected Highways in Virginia

Parking Demand Characteristics

In general, the demand for commercial truck parking facilities on the highways included in the Phase II study was not as high as for those on I-81 in the Phase I study. [14] The following sections summarize the demand characteristics at the rest areas and truck stops along the different roadways in this Phase II study.

Demand at Rest Areas

Data analysis on truck parking demand at rest areas indicated that different corridors had different patterns. Truck parking accumulation at rest areas along I-64 was significantly lower than on other corridors such as I-77, I-85, and I-95. Truck parking accumulation at rest areas along I-66 was also different than on other corridors because of the relatively shorter average stay. The average truck parking duration along I-66 was 10 to 15 minutes, and no truck was parked for more than 2 hours during the period of field observation. The average duration at rest areas along other interstate highways was 20 to 60 minutes, and about 25 percent of the trucks were parked for more than 2 hours.

Demand at Truck Stops

Accumulation and duration data were obtained at 12 truck stops in this Phase II study. Six were on I-95, three on I-85, one on I-77, and one on I-64. In addition, data were collected at one truck stop on US 29. Truck parking demand varied among the different corridors. Parking demand at truck stops along I-95 was the highest, as shown in Figure 4.

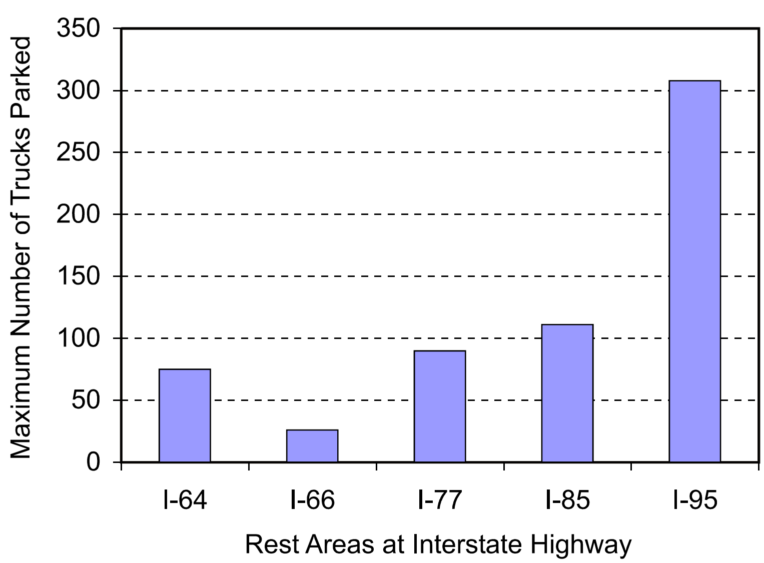

Figure 4. Observed Maximum Truck Parking Accumulations at Rest Areas

An analysis of the results of the accumulation and duration data also indicated that the variation of these characteristics during the day was similar for all truck stops except those along I-77. Duration and accumulation tended to increase as the day went by in truck stops along I-64, I-85, I-95, and US 29, but not along I-77. Figures 5 and 6 illustrate this phenomenon for parking accumulation. Figure 5 shows parking accumulation for the different times of day at the Travel American truck stop at Exit 89 Northbound on I-95. Figure 6 shows the parking duration for the different times of day at Exxon at Exit 8 Southbound on I-77. These two figures showed the significant difference in parking accumulation between the two truck stops. A possible reason was that the truck stops along I-77 provided limited services that did not attract drivers to have long-term stays, coupled with their proximity to I-81, which has truck stops with a wider range of services.

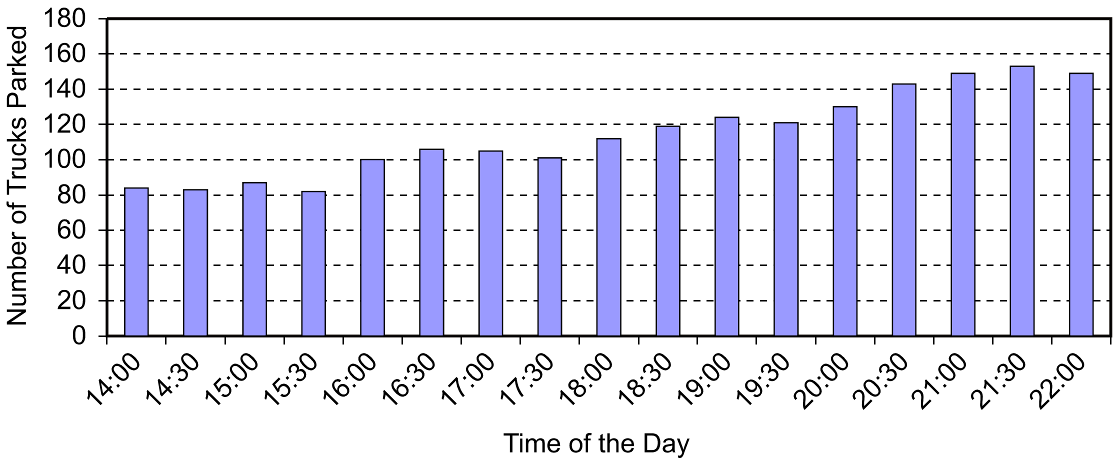

Figure 5. Accumulation vs. Time of Day at Travel American Center, Exit 89, I-95

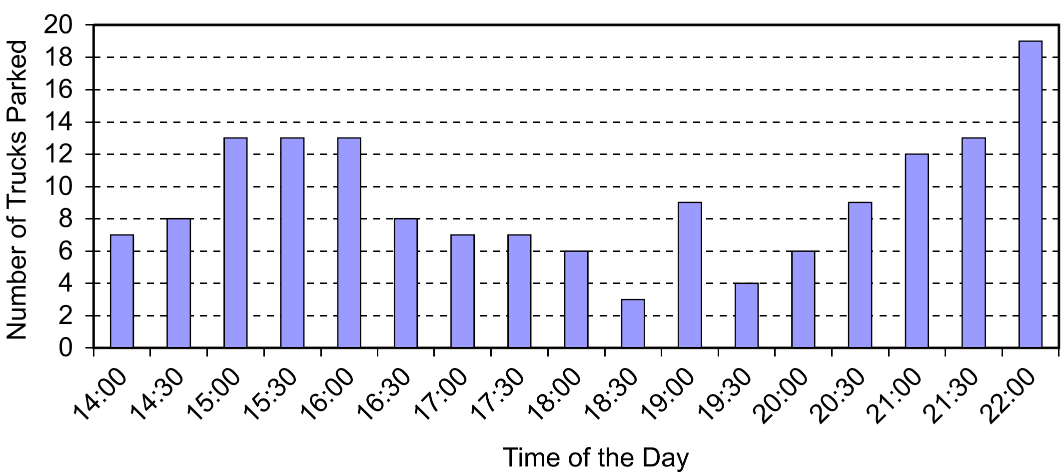

Figure 6. Accumulation vs. Time of Day at Exxon, Exit 8, I-77

An unexpected result was observed in that contrary to what was found on I-81 in the Phase I study, [14] the maximum parking accumulation at most truck stops did not occur by 10 P.M. Because of this, additional data were collected at 11 truck stops between midnight and early morning to obtain the maximum truck parking accumulation at the truck stops. This supplemental data gave the researchers good indications of the maximum parking accumulation. The results indicated that the parking accumulation increased with time of day along all corridors but increased, then decreased, and increased again with time of day along I-77. Only three trucks were parked at early morning at Exxon at Exit 8 of I-77. Two other truck stops along I-77 were about half full. This suggests that most truck drivers did not want to have an overnight stay along I-77.

Maximum parking durations on I-95 varied from 107.65 minutes at Mr. Fuel #2 truck stop at Exit 104 on I-95 to 365.38 minutes at Richmond Travel Center at Exit 89 on I-95. Figure 7 shows the average duration at the Travel American truck stop at Exit 89 Northbound of I-95, which is similar to that for truck stops on I-64 and I-85.

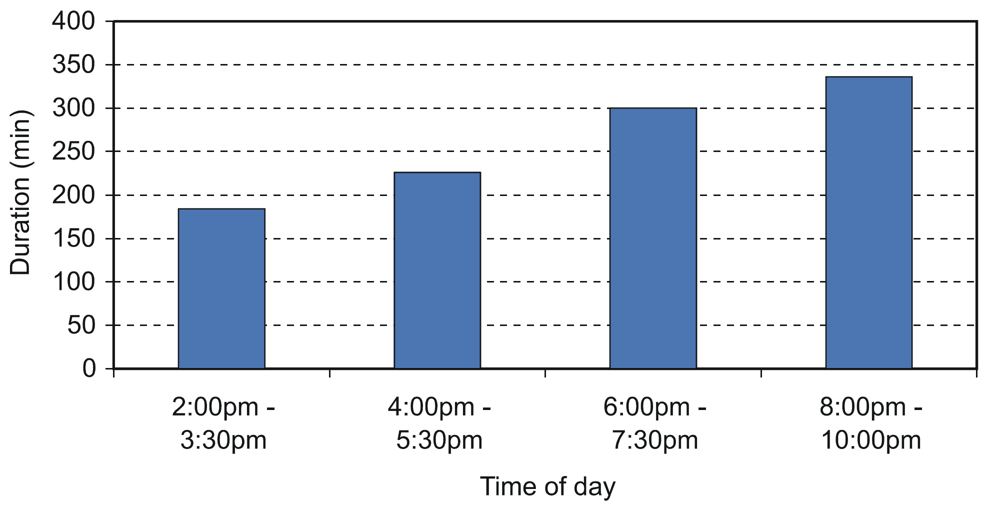

Figure 7. Average Duration vs. Time of Day at Richmond Travel Center, Exit 89, I-95

Estimation of Illegal Parking

There was no illegal parking on the shoulders of the roadways and ramps of the interchanges along I-64, I-77, and I-85. Illegal parking involving an average of six vehicles was observed on interchange ramps at Exits 118 and 140 along I-95.

Illegal parking on shoulders of the entrances and exits at rest areas was common. Some trucks were parked illegally while regular parking spaces were available. On average, the study results showed that 5 percent of the parking spaces were not being used in those situations. A possible reason is that the drivers did not have correct information on the availability of parking spaces, which indicates the necessity for real time information. When illegal parking existed while legal parking spaces were available, the number of illegally parked vehicles considered as excess demand (*net illegally parked vehicles)* was the total number of illegally parked vehicles minus the unused legal parking spaces.

Estimation of Current Parking Deficiency

On the whole, the parking deficiencies found on the highways in this Phase II study were not as severe as those found on I-81 in the Phase I study.[14]

- *Along I-95,* the maximum demand for parking exceeded the number of available parking spaces at most truck stops by 10 to 20 percent. On average, the maximum demand at rest areas exceeded the number of available parking spaces by about 32 percent. However, severe shortages of parking spaces were observed at two of the truck-only rest areas on the SB and NB of milepost 154, where demand exceeded supply by about 47 percent. Several trucks were parked along the entrance and exit ramps of the rest areas. More than 12 illegally parked trucks were observed on the ramps of one interchange along I-95 in North Carolina, just across the Virginia/North Carolina border. This may be due to stricter enforcement in Virginia than in North Carolina.

- *On I-85 overall,* there was no shortfall of parking spaces at the truck stops. The shortfall of truck parking spaces at the rest areas was about 6 percent. Illegally parked trucks were observed on entrance and exit ramps of rest areas along this route during peak demand periods.

- *On I-66,* the shortfall at the two rest areas at milepost 48 (EB and WB) was about 24 percent. Illegally parked trucks were observed.

- *Along I-64 and I-77,* no parking shortfall was observed at truck stops. The shortfall at rest areas on I-77 was about 43 percent. This did not include the section of I-77 that overlaps with I-81 and was included in Phase I of the study. No shortfall was observed at rest areas on I-64

Table 8 shows the demand/supply ratios at rest areas and truck stops in this study.

Table 8. Current Truck Parking Demand/Supply Ratios Along Interstates in Virginia

Parking Facility Type	Demand/Supply Ratios					
	I-64	I-66	I-77	I-85	I-95	US 29
Rest areas	0.78[a]	1.24	1.43	1.06	1.32	N/A[d]
Truck stops	0.88	N/A[b]	0.50[c]	1.00	1.22	0.52[e]

[a]EB 213 rest area at I-64 was closed.
[b]No truck stop along I-66.
[c]Excluding overlap sections with I-81.
[d]No rest area along US 29.
[e]Only one site investigated.

Survey Results

The return rate was about 27.4 percent for the truck driver survey forms left at the truck stops. The rate was lower than in the Phase I study because researchers were not allowed to interview the truck drivers. The owners/operators thought the survey was either another way that the government affected their business or a kind of solicitation. Some truck stop owners/operators did not allow the researchers to leave the survey forms on their property. The response rate of the truck stop owner/operator survey was also lower than in the Phase I study. One possible reason was that in the Phase I study, most owners/operators knew of the planned improvement project on I-81 and wanted to express their opinions.[14]

Truck Driver Survey

The survey forms were left at several truck stops along I-77, I-85, and I-95. Forty-seven of 150 forms were returned from truck drivers on I-95, 22 of 75 forms were returned from I-85, and 20 of 100 forms were returned from I-77. The vast majority of trucks were five-axle tractor-semi-trailers. More than 90 percent of the truck drivers did not have co-drivers. About 30 percent were independent drivers, which was a higher percentage than on I-81.

The survey found the following:

- *About 60 percent of drivers said there were too few parking spaces at rest areas and truck stops.* About 60 percent of the drivers on I-95, 60 percent on I-85, and about 75 percent on I-77 said that there were usually spaces available when they arrived at a specific rest area or truck stop at which they had planned in advance to stop. These drivers indicated that the availability of parking spaces depended on the time of day. Parking spaces were usually full by late evening and early morning at most truck stops.

- *No charges were imposed on truck drivers for the use of almost all of the truck stops included in this study.* A few truck stops charge a fee if drivers are not their patrons (i.e., not making use of any of the services, such as fuel or restaurant) or if drivers drop their trailers overnight.

- *A total of 20 percent of the drivers indicated they would choose to stop along the roadway if they were no parking spaces available at their initial choice of rest area or truck stop.*

- *About 80 percent of the drivers preferred to use truck stops for long rests and about 60 percent preferred to use rest areas when they needed to take a break of less than 2 hours.* This is mainly attributable to the 2-hour maximum stay restriction at Virginia rest areas.

- *Almost 100 percent of drivers were equipped with communication devices such as CB radios, cellular phones, or onboard computers.*

- *The availability of shower rooms and the location of truck stops were the most important factors that influenced drivers in selecting a truck stop for a short or a long stay. The number of parking spaces and whether parking was free also influenced their decisions.*

Truck Stop Owner/Operator Survey

Thirteen of 25 (52%) of the surveys for the truck stop owners/managers were completed and returned. The findings were as follows:

- *Half of the truck stop owners/operators along I-95 believed that the truck facilities were adequate.*

- *Almost all the truck stop owners/operators along other routes believed that the number of truck parking spaces in their truck stops during nighttime was about right.*

- *Most of the responding owners/operators perceived no variation in the demand of truck parking spaces among the seasons (winter, spring, summer, and fall). However, they believed the demand fluctuated between daytime and nighttime.*

Model Testing and Development

The Phase I study provided two regression models on truck parking demand, which were based on parking information along I-81 in Virginia.[14] Table 9 shows the coefficients of the models.[14] Although these models gave good predictions on two validation sites along I-81, the researchers were not confident that they could be directly applied to other interstate highways. Because there was no significant difference in the results with the two models, the researchers selected one model (Model 2) with a more reasonable parking duration assumption for the Phase II study. The model formula is shown as Equation 2.

$$\text{Accumulation} = -1475.79228 + 1.54780*\text{percentTRUCK} + 0.13912*\text{Duration\_2} + 0.05898*\text{TotalTruck} - 114.32799*\text{DIST\_81} + 103.75365*\text{DIST\_TS} + 13.80663*\text{DIST\_RA} + 919.61570*\text{SERVICE}\ (R^2 = 0.9294) \qquad \text{[Eq. 2]}$$

Table 9. Coefficients of Regression Models for Phase I Study[14]

Independent Variable	Model 1	Model 2	Sign
Intercept	–1586.89036	–1475.79228	–
Percent of truck	1.41039	1.54780	+
Parking duration	0.1556301	0.13912	+
Total truck volume	0.06955	0.05898	+
Distance to I-81	–123.29288	–114.32799	–
Distance to nearest truck stop	111.95632	103.75365	+
Distance to nearest rest area	14.22398	13.80663	+
Service provided	988.99725	919.61570	+

Phase I Model Testing

The model was first tested for its applicability using the data on the corresponding dependent and independent variables collected during the Phase II study. The data obtained from four truck stops along I-95, two on I-85, one on I-77, and one on I-64 were used to test the applicability of the model. The Chi-squared test at a 5 percent significance level was used to test the applicability of the model for the data collected from 4 P.M. to 10 P.M. The results indicated that the model could be accepted to represent the data at two truck stops on I-95: Richmond Travel Center at Exit 89 and Ashland Travel Center at Exit 92. Figures 8 and 9 show the predicted parking accumulation compared with the field data for these two truck stops.

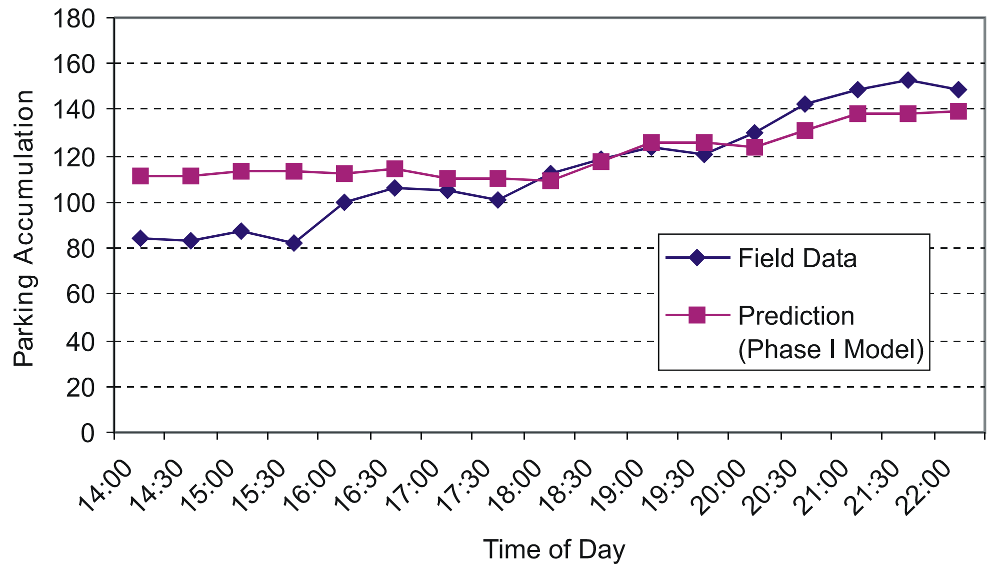

Figure 8. Estimated Parking Accumulation from the Model vs. Field Data at Richmond Travel Center

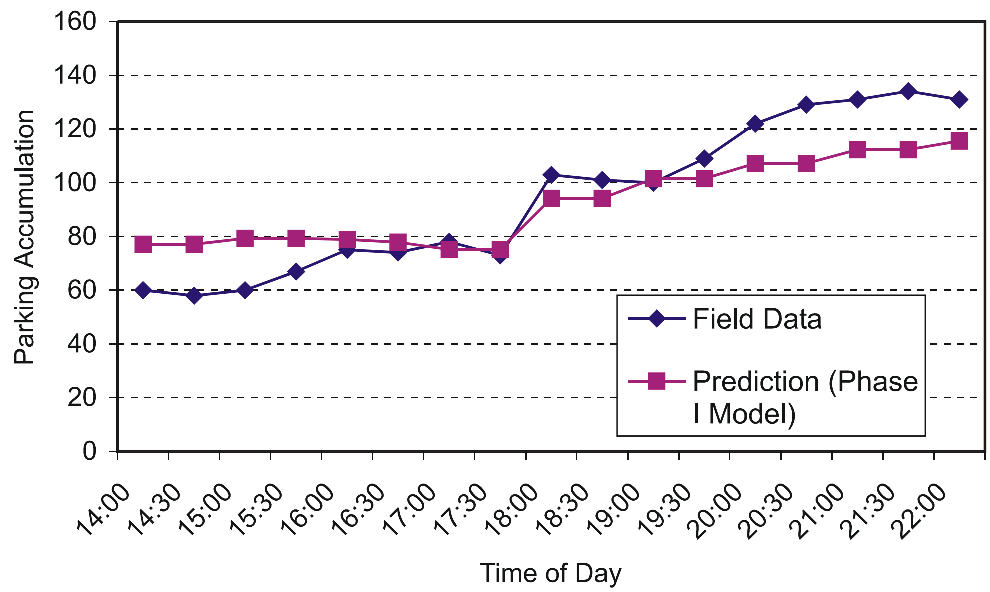

Figure 9. Estimated Parking Accumulation from Model vs. Field Data at Ashland Travel Center

Tables 10 and 11 show the results of the Chi-squared test. Unfortunately, the model could not be used to represent the data at two other truck stops on I-95: Doswell All American Travel Plaza at Exit 98 and Flying J Travel Plaza at Exit 104. In addition, the results of the Chi-squared tests on the data collected at truck stops along I-64, I-77, and I-85 showed that the I-81 model could not represent these data. It was therefore decided to develop new models that would better represent the data collected.

Table 10. Chi-squared Test at Richmond Travel Center

No	ACCU-Field data (f0)	Prediction (fe)	f0-fe	(f0-fe)*(f0-fe)	(f0-fe)*(f0-fe)/fe
1	100	112.7877728	−12.7877728	163.5271332	1.449865789
2	106	114.4572128	−8.4572128	71.52444834	0.624901189
3	105	110.2639228	−5.2639228	27.70888324	0.251296005
4	101	110.2639228	−9.2639228	85.82026564	0.778316819
5	112	109.1292078	2.8707922	8.241447856	0.075520092
6	119	117.3372878	1.6627122	2.76461186	0.023561239
7	124	126.2775028	−2.2775028	5.187019004	0.041076351
8	121	126.2775028	−5.2775028	27.8520358	0.220562136
9	130	124.2807528	5.7192472	32.70978853	0.263192713
10	143	131.5149928	11.4850072	131.9053904	1.002968464
11	149	137.8756378	11.1243622	123.7514344	0.897558382
12	153	137.8756378	15.1243622	228.746332	1.659077235
13	149	139.5636978	9.4363022	89.04379921	0.638015477
				TOTAL	7.925911891
Df = 13 − 1=12	alpha=5%	Theoretical Chi-squared=21.03		7.926<21.03	Accept it

Table 11. Chi-squared Test at Ashland Travel Center

No	ACCU-Field data (f0)	Prediction (fe)	f0-fe	(f0-fe)*(f0-fe)	(f0-fe)*(f0-fe)/fe
1	75	78.8567066	−3.8567066	14.8741858	0.188622965
2	74	77.8828666	−3.8828666	15.07665303	0.193581126
3	78	75.2373766	2.7626234	7.63208805	0.101440114
4	73	75.2373766	−2.2373766	5.00585405	0.066534139
5	103	94.1534216	8.8465784	78.26194939	0.831217263
6	101	94.1534216	6.8465784	46.87563579	0.49786439
7	100	101.5458366	−1.5458366	2.389610794	0.023532336
8	109	101.5458366	7.4541634	55.56455199	0.547186904
9	122	107.1276066	14.8723934	221.1880854	2.064716019
10	129	107.1276066	21.8723934	478.401593	4.465717178
11	131	112.3092516	18.6907484	349.3440758	3.110554747
12	134	112.3092516	21.6907484	470.4885662	4.18922359
13	131	115.5451116	15.4548884	238.8535755	2.067188929
				TOTAL	18.3473797
Df=13−1=12	alpha=5%	Theoretical Chi-squared=21.03		18.34<21.03	Accept it

New Model Development

Although the Phase I model was not acceptable for data for two truck stops on I-95 (Doswell All American Travel Plaza at Exit 98 and Flying J Travel Plaza), it was recognized that truck stops along I-95 and I-81 had similar large truck parking patterns. Therefore, the datasets for I-81 and I-95 excluding that for Doswell All American Travel Plaza were used as training data to develop a new model for these two highways. The data obtained at Doswell All American Travel Plaza were reserved for testing the new model. Multiple linear regression analysis was used to develop the models. Another model was developed using the combined dataset for I-64, I-77, and I-85, excluding the data for Thrift Mart at Exit 63 on I-85, as the training data. The dataset obtained for Thrift Mart was used as the reserved dataset. The reserved datasets were used for testing the applicability of the models developed.

Model for I-81 and I-95

The variables finally included in the new model for I-81 and I-95 are shown here together with their statistical characteristics.

Dataset Statistical Description:
Page/Date/Time 1 12-12-2002 14:51:47
Database D:\modeldata2-95-81.S0
Dependent ACCUMULATION

Variable	Count	Mean	Standard Deviation	Minimum	Maximum
percentTRUCK	115	29.83652	16.70526	12.2	77
Duration	115	216.887	95.59763	42	361
DIST_mainline	115	0.3792	0.2393121	0.15	0.916
DIST_RA	115	10.61043	8.054762	1	26
Service	115	0.8260869	0.3806935	0	1
TruckVolume*DIST_TS	115	65857.35	20504.99	35980	102727.6
ACCUMULATION	115	108.2435	53.36281	10	210

where

percentTRUCK	= percent of trucks in traffic stream in half-hour intervals
Duration	= average parking duration at truck stop at different time periods
DIST_mainline	= distance from truck stop to mainline
DIST_RA	= distance from truck stop to nearest rest area
Service	= dummy variable for measuring difference of services between large and small truck stops (number of spaces>60, service=1; otherwise, service=0)
TruckVolume*DIST_TS	= multiplication of daily truck volume and distance to nearest truck stop
ACCUMMULATION	= number of trucks parked in truck stop at different times.

Table 12. Correlation Matrix of Dataset for I-81 and I-95

Pearson Correlation Factor	Percent TRUCK	Duration	DIST_ML	DIST_RA	Service	TruckVolume* DIST_TS
PercentTRUCK	1	0.101298	–0.13236	–0.458637	–0.238167	–0.561572
Duration	0.1013	1	–0.01052	0.060825	0.226988	–0.07913
DIST_mainline	–0.1324	–0.01052	1	–0.353115	0.257271	0.383728
DIST_RA	–0.4586	0.060825	–0.35312	1	0.22945	–0.322359
Service	–0.2382	0.226988	0.257271	0.22945	1	–0.165063
TruckVolume*DIST_TS	–0.5616	–0.07913	0.383728	–0.322359	–0.165063	1

Results of the correlation analysis for these variables in the combined dataset for I-81 and I-95 are shown in Table 12. These results show that all of the correlation factors were much less than 0.65.

The parking model obtained for the combined dataset for I-81 and I-95 is given as Equation 3:

ACCUMULATION = –217.3026 + 2.628309*percentTRUCK + 0.1621317*Duration – 27.4093*DIST_mainline + 1.99189*DIST_RA + 131.7269*Service + 1.97887E-03 * TruckVolume*DIST_TS [Eq. 3]

The properties of the regression coefficients are as follows:

Independent Variable	Regression Coefficient	Standard Error	Lower 95% C.L.	Upper 95% C.L.	Standardized Coefficient
Intercept	–217.3026	26.17544	–269.1869	–165.4183	0.0000
percentTRUCK	2.628309	0.2661496	2.100755	3.155864	0.8228
Duration_2	0.1621317	2.050365E-02	0.1214899	0.2027735	0.2905
DIST_mainline	–127.4093	9.401011	–146.0437	–108.7749	–0.5714
DIST_RA	1.99189	0.4502971	1.099323	2.884457	0.3007
Service	131.7269	6.293997	119.2511	144.2027	0.9397
TruckVolume*DIST_TS1.97887E-03			2.028141E-04	1.576857E-03	2.380883E-03 0.7604
R-Squared	0.875537				
T-Critical	1.982173				

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	–217.3026	26.17544	–8.3018	0.000000	Reject Ho	1.000000
percentTRUCK	2.628309	0.2661496	9.8753	0.000000	Reject Ho	1.000000
Duration_2	0.1621317	2.050365E-02	7.9075	0.000000	Reject Ho	1.000000
DIST_mainline	–127.4093	9.401011	–13.5527	0.000000	Reject Ho	1.000000
DIST_RA	1.99189	0.4502971	4.4235	0.000023	Reject Ho	0.992322
Service	131.7269	6.293997	20.9290	0.000000	Reject Ho	1.000000
C12	1.97887E-03	2.028141E-04	9.7571	0.000000	Reject Ho	1.000000
R-Squared	0.875537					

The results obtained from testing the applicability of the model at the Doswell All American Travel Plaza on I-95 are shown in Figure 10. The results of the Chi-squared analysis shown in Table 13 indicate that the model can be accepted as representing the data at this truck stop. As shown earlier, the Phase I model could not represent the data for this truck stop.

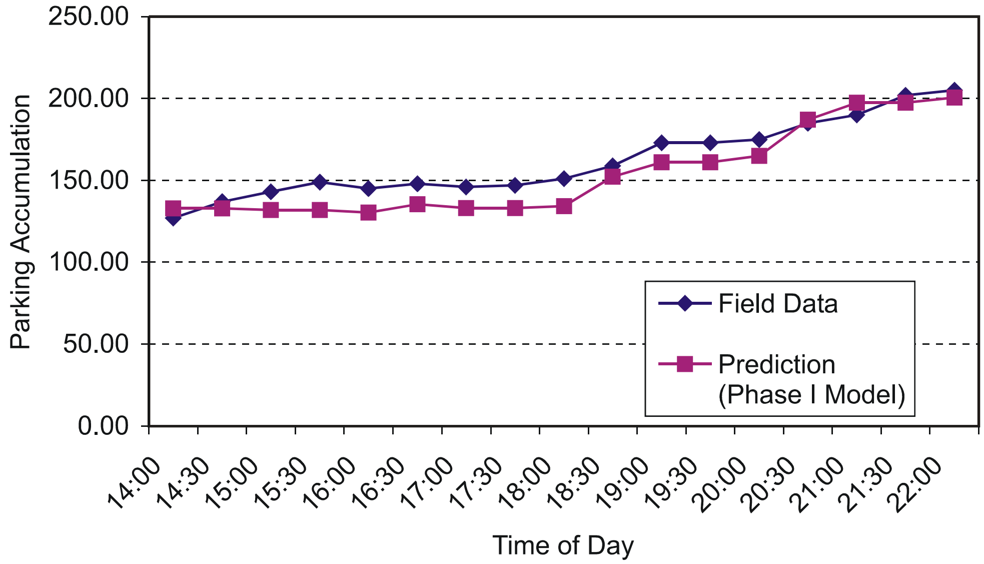

Figure 10. Estimated Parking Accumulation from Model vs. Field Data at Doswell All American Travel Plaza (New Model)

Table 13. Chi-squared Test at Doswell All American Travel Plaza (New Model)

No	ACCU-Field data (f0)	Prediction (fe)	f0-fe	(f0-fe)*(f0-fe)	(f0-fe)*(f0-fe)/fe
1	145.00	130.3648975	14.6351025	214.186224	1.642974666
2	148.00	135.3909802	12.6090198	158.9873793	1.17428339
3	146.00	133.0255021	12.9744979	168.3375947	1.265453556
4	147.00	133.0255021	13.9744979	195.2865904	1.468038739
5	151.00	134.3396566	16.6603434	277.5670408	2.066158629
6	159.00	152.1741436	6.82585636	46.59231502	0.306177606
7	173.00	161.1103942	11.8896058	141.3627251	0.877427715
8	173.00	161.1103942	11.8896058	141.3627251	0.877427715
9	175.00	165.0528577	9.94714226	98.9456391	0.599478497
10	185.00	187.1027689	−2.10276894	4.421637223	0.023632131
11	190.00	197.353174	−7.35317404	54.06916849	0.273971618
12	202.00	197.353174	4.64682596	21.59299148	0.109412943
13	205.00	200.5071448	4.49285516	20.18574747	0.100673457
				TOTAL	10.78511066
Df=13-1=12	Alpha=5%	Theoretical Chi-squared=21.03		10.78<21.03	Accept it

Model for I-64, I-77, and I-85

The statistical characteristics of the variables in the model for the combined dataset are as follows. Table 14 gives the correlation matrix for independent variables in the dataset for I-64, I-77, and I-85. It can be seen that all correlation factors are much below 0.35.

Dataset Statistical Description:
Page/Date/Time **1 12-13-2002 13:04:03**
Database **D:\modeldata1.S0**
Dependent **Accumulation**

Variable	**Count**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Percent_of_Truck	72	21.56611	8.242234	12.4	52.56
Duration_1	72	175.5	88.06576	50	327
Service	72	0.25	0.4360514	0	1
TruckVolume*DIST_TS	72	83038.6	47479.47	12532.5	137741.4
Accumulation	72	26.20833	17.46702	3	77

Table 14. Correlation Matrix of Dataset for I-64, I-77 and I-85

Pearson Correlation Factor	**PercentTRUCK**	**Duration**	**Service**	**TruckVolume*DIST_TS**
PercentTRUCK	1	0.154689	0.181874	0.122137
Duration	0.154689	1	0.245371	0.09873
Service	0.181874	0.245371	1	0.342213
TruckVolume*DIST_TS	0.122137	0.09873	0.342213	1

The model obtained for I-64, I-77, and I-85 is given as Equation 4.

ACCUMULATION = –7.631802 + 0.2022095*Percent_of_Truck
+ 7.625756E-02*Duration + 22.13848*Service + 1.271871E-04*
TruckVolume*DIST_TS [Eq. 4]

The properties of the regression coefficients are:

Independent Variable	**Regression Coefficient**	**Standard Error**	**Lower 95% C.L.**	**Upper 95% C.L.**	**Standardized Coefficient**
Intercept	–7.631802	2.611098	–12.84357	–2.420029	0.0000
Percent_of_Truck	0.2022095	9.131891E-02	1.993617E-02	0.3844828	0.0954
Duration_1	7.625756E-02	8.652085E-03	5.898793E-02	0.0935272	0.3845
Service	22.13848	1.852202	18.44147	25.8355	0.5527
C12	1.271871E-04	1.648105E-05	9.429078E-05	1.600834E-04	0.3457
R-Squared	0.881788				
T-Critical	1.996008				

Independent Variable	**Regression Coefficient**	**Standard Error**	**T-Value (Ho: B=0)**	**Prob Level**	**Decision (5%)**	**Power (5%)**
Intercept	–7.631802	2.611098	–2.9228	0.004726	Reject Ho	0.821406
Percent_of_Truck	0.2022095	9.131891E-02	2.2143	0.030213	Reject Ho	0.588072
Duration_1	7.625756E-02	8.652085E-03	8.8138	0.000000	Reject Ho	1.000000
Service	22.13848	1.852202	11.9525	0.000000	Reject Ho	1.000000
C12	1.271871E-04	1.648105E-05	7.7172	0.000000	Reject Ho	1.000000
R-Squared	0.881788					

Figure 11 shows the estimated accumulation obtained from the model and the field data. The results of the Chi-squared test shown in Table 15 also indicate that the new model can be accepted as representing the data at the Thrift Mart.

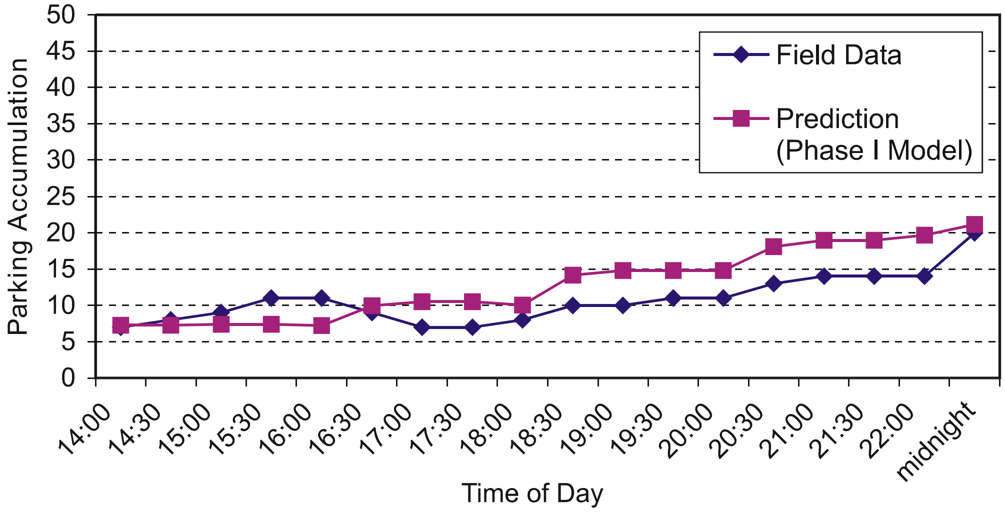

Figure 11. Estimated Parking Accumulation Obtained from Model vs. Field Data at Thrift Mart

Table 15. Chi-squared Test at Thrift Mart (New Model)

No	ACCU-Field data (f0)	Prediction (fe)	f0-fe	(f0-fe)*(f0-fe)	(f0-fe)*(f0-fe)/fe
1	9.00	9.965716206	–0.96571621	0.93260779	0.093581612
2	7.00	10.48943881	–3.48943881	12.17618321	1.160804065
3	7.00	10.48943881	–3.48943881	12.17618321	1.160804065
4	8.00	10.03648953	–2.03648953	4.147289609	0.413221136
5	10.00	14.15439777	–4.15439777	17.25902084	1.219339821
6	10.00	14.7893356	–4.7893356	22.9377355	1.550964568
7	11.00	14.7893356	–3.7893356	14.3590643	0.970906651
8	11.00	14.80551236	–3.80551236	14.48192433	0.978144084
9	13.00	18.08458744	–5.08458744	25.85302944	1.429561472
10	14.00	18.98441972	–4.98441972	24.8444399	1.308675233
11	14.00	18.98441972	–4.98441972	24.8444399	1.308675233
12	14.00	19.66384364	–5.66384364	32.07912473	1.63137611
13	20	21.13795089	–1.13795089	1.29493223	0.06126101
				TOTAL	13.28731506
Df=13-1=12	alpha=5%	Theoretical Chi-squared=21.03		13.28<21.03	Accept it

Estimation of Future Parking Demand

To apply the new models to predict the 2010 and 2020 maximum accumulation at each truck stop, the future values of the independent variables were determined. However, only future daily truck-trailer traffic (DTTT) and maximum hourly percentage of truck trailer (HPTT) were

Table 16. Linear Regression Models for Estimating DTTT

Road	Direction	Regression Equation	R^2
I-64	EB	Y(x) = 64.89x – 127990	0.94
	WB	Y(x) = 74.17x – 146532	0.88
I-77	SB	Y(x) = 111.30x – 217119	0.80
	NB	Y(x) = 151.5x – 297340	0.85
I-85	SB	Y(x) = 90.11x – 177761	0.79
	NB	Y(x) = 38.88x – 77145	0.57
I-95	SB	Y(x) = 229.48x – 450540	0.69
	NB	Y(x) = 175.78x – 343061	0.43

General equation: Y(x)=mx + b, where x = year for projection and Y(x) = projected daily truck trailer volume.

required, as the other variables would not change. Based on the historical data from 1997 through 2002, simple linear regression models for different routes were used to forecast the future daily truck-trailer traffic. Table 16 shows the regression models for estimating the DTTT. The future values for maximum hourly percentage of truck were estimated using two scenarios. The first assumes that the current hourly percentages of truck on the mainline remain the same, and the second assumes they increase by 5 percent.

Parking demand was forecast in several steps. First, the future maximum accumulations were determined at the truck stops for which data were available using the appropriate equations developed. Equation 3 was used for truck stops on I-81 and I-95. Equation 4 was used for truck stops on I-64, I-77, and I-85. Then, for each truck stop at which accumulation data were not available, the year 2002 (base year) maximum accumulation was obtained by multiplying the average percentile maximum accumulation for the corridor on which the truck stop was located by the number of truck parking spaces at the location. For example, the average percentile year 2002 maximum accumulation at truck stops on I-95 for which data were available was used to estimate the year 2002 maximum accumulation at Service Town Travel Plaza at Exit 133 on I-95 for which no data were available. For each truck stop at which accumulation data were not available, the predicted 2010 and 2020 maximum accumulation values were obtained by multiplying the estimated 2002 maximum accumulation value by appropriate percentile increases. For example, the average percentile increase in maximum accumulation between 2002 and 2010 for truck stops on I-95 for which data were available was used as the multiplying factor to estimate the maximum accumulation in 2010 at Service Town Travel Plaza. For each rest area, the illegal parking recorded during the data collection phase was added to the estimated accumulation for the nearest rest area. The percentage increase for truck stops on the corresponding corridor was then applied to the rest area accumulations to determine the estimated future accumulations. Finally, the parking demands of truck stops and rest areas were added for each segment on every interstate corridor.

Since the thrust of the study was not the primary highways and data were collected at only one primary highway, i.e., US 29, it was not feasible to develop a separate model for the primary highways. However, an analysis was carried out for the data for US 29 to estimate the impact on future demand, if it is assumed that the increase for parking demand for US 29 is the same as for I-64, I-77, and I-85. Table 17 shows the results obtained for maximum accumulation at each truck stop. Table 18 shows the maximum accumulation at each rest area.

Table 17. Maximum Truck Parking Accumulation at Each Truck Stop

Route	Name	Space	Current Parking Estimation	Prediction (2010)-1[a]	Prediction (2010)-2[b]	Prediction (2020)-1[a]	Prediction (2020)-2[b]
I-64	Zion Crossroads (Citgo)	44	39	45	46	51	52
I-64	Big Charlie's Truck Stop	205	182	210	214	238	242
I-64	Frank's Trucking Center	74	66	76	77	86	87
I-85	Simmons Bracey Travel	85	59	67	68	71	72
I-85	Circle D Mart (Chevron)	25	19	22	23	24	24
I-85	Mapco Express	34	34	41	42	45	46
I-85	Thrift Mart (Exxon)	25	18	21	21	22	23
US 29	Quarles	50	26	30	31	33	34
US 29	Shell	35	18	21	22	23	24
US 29	Mapco Express (East Coast)	15	8	9	9	10	10
I-77	Chevron	59	26	31	32	33	34
I-77	Exxon	41	32	38	39	41	42
I-77	Citgo	15	9	10	11	11	11
I-95	Simmons Travel Center	55	70	82	86	96	101
I-95	Sadler Travel Plaza (Shell)	130	168	197	207	231	242
I-95	Davis Truck Plaza (Chevron/Exxon)	90	119	139	147	163	171
I-95	Richmond Travel Center	135	162	189	202	218	231
I-95	Ashland Travel Center	134	156	188	201	217	230
I-95	Doswell All American Travel Plaza (Texaco)	215	246	279	292	329	342
I-95	Flying J Travel Plaza	239	290	285	298	340	353
I-95	Pilot Travel Center #291	55	67	78	82	92	96
I-95	Mr. Fuel #2	20	24	28	30	33	35
I-95	Petro Shopping Center #56	267	324	379	400	445	466
I-95	RaceTrac Fuel Stop	23	28	33	34	38	40
I-95	Servicetown Travel Plaza	207	251	294	310	345	361
Total		2277	2440	2793	2926	3236	3369
Demand/ Supply			1.072	1.226	1.285	1.421	1.480

[a]Assuming no increase in truck percentage (low scenario).
[b]Assuming an increase of 5% in truck percentage (high scenario).

Tables 19 and 20 show the estimated commercial truck parking demand for the different sections of highways for each of the two scenarios. In scenario 1, the midnight hourly truck trailer percentages are the same as current values (low scenario). In scenario 2, the midnight hourly truck trailer percentages were increased by 5 percent (high scenario).

Table 18. Maximum Truck Parking Accumulation at Each Rest Area

Route	Direction	Mile marker	Truck Space	Current Maximum Observation	Prediction (2010)-1[a]	Prediction (2010)-2[b]	Prediction (2020)-1[a]	Prediction (2020)-2[b]
I-64	Eastbound	2	0					
I-64	Eastbound	13	16	12	14	15	16	17
I-64	Eastbound	105	19	15	17	17	19	20
I-64	Westbound	113	14	9	10	11	12	12
I-64	Westbound	168	11	9	10	11	12	12
I-64	Eastbound	169	9	10	12	12	13	13
I-64	Eastbound	213	34	Closed (26)	30	31	34	35
I-64	Westbound	213	25	18	21	21	24	24
I-66	Eastbound	48	10	16	19	19	20	21
I-66	Westbound	48	11	10	12	12	13	13
I-77	Northbound	1	19	26	31	32	33	34
I-77	Northbound	59	20	29	34	35	37	38
I-77	Southbound	61	24	35	42	43	45	46
I-85	Northbound	1	25	21	24	25	26	27
I-85	Northbound	32	13	19	22	22	24	24
I-85	Southbound	32	13	12	14	14	15	15
I-85	Northbound	55	15	16	19	19	20	20
I-85	Southbound	55	20	23	27	27	29	30
I-95	Northbound	1	0					
I-95	Northbound	37	40	34	40	42	47	49
I-95	Northbound	107	40	40	47	49	55	58
I-95	Southbound	107	20	28	33	35	38	40
I-95	Southbound	131	21	29	34	36	40	42
I-95	Northbound	154	60	93	109	115	128	134
I-95	Southbound	154	61	96	112	119	132	138
I-95	Northbound	155	0					
I-95	Southbound	155	0					
			506	600				
TOTAL			540		732	761	831	860
Demand/ Supply				1.19	1.35	1.41	1.54	1.59

[a]Assuming no increase in truck percentage (low scenario).
[b]Assuming an increase of 5% in truck percentage (high scenario).

Table 19. Parking Demand on Different Section of the Roadways in Scenario 1

Road	Sec.	Begin Milepost	End Milepost	Parking Spaces	Current Parking Demand	Parking Demand in 2010 (1)	Parking Demand in 2020 (1)
I-64	1	0	56	16	12	14	16
	2	87	124	33	24	27	31
	3	124	177	64	58	67	76
	4	200	275	264	200	261	296
	5	275	298	74	66	76	86
I-66	1	0	23	0	0	0	0
	2	23	64	21	26	31	33
I-77	1	0	32	119	84	100	107
	2	40	66	59	73	86	93
I-85	1	0	34	136	111	127	136
	2	34	65	119	110	130	140
I-95	1	0	37	315	391	458	537
	2	37	65	81	97	114	133
	3	83	133	1088	1296	1459	1712
	4	133	170	328	440	515	605
US 29	1	Whole Route		100	52	60	66
Total[a]				2717	2988	3465	4001

[a]US 29 not included.

Table 20. Parking Demand on Different Section of the Roadways in Scenario 2

Road	Sec.	Begin Milepost	End Milepost	Parking Spaces	Current Parking Demand	Parking Demand in 2010 (2)	Parking Demand in 2020 (2)
I-64	1	0	56	16	12	15	17
	2	87	124	33	24	28	32
	3	124	177	64	58	69	77
	4	200	275	264	200	266	301
	5	275	298	74	66	77	87
I-66	1	0	23	0	0	0	0
	2	23	64	21	26	31	34
I-77	1	0	32	119	84	103	110
	2	40	66	59	73	89	95
I-85	1	0	34	136	111	130	138
	2	34	65	119	110	132	142
I-95	1	0	37	315	391	483	562
	2	37	65	81	97	120	139
	3	83	133	1088	1296	1540	1793
	4	133	170	328	440	543	633
US 29	1	Whole Route		100	52	62	67
Total[a]				2717	2988	3626	4160

[a]US 29 not included.

Estimation of Future Parking Deficiency

Table 21 shows the associated deficiencies in parking spaces for each segment of the highway system, assuming no increase in parking spaces at the truck stops.

Table 21. Deficiency of Commercial Truck Parking Spaces

Road	Sec.	Parking Spaces	Current Deficiency	Deficiency in 2010 (1) (Low)	Deficiency in 2010 (2) (High)	Deficiency in 2020 (1) (Low)	Deficiency in 2020 (2) (High)
I-64	1	16	–4	–2	–1	0	1
	2	33	–9	–6	12	15	16
	3	64	–6	3	5	12	13
	4	264	–64	–3	2	32	37
	5	74	–8	2	3	12	13
I-66	1	0	0	0	0	0	0
	2	21	5	10	10	12	13
I-77	1	119	–35	–19	–16	–12	–9
	2	59	14	27	30	34	36
I-85	1	136	–25	–9	–6	0	2
	2	119	–9	11	13	21	23
I-95	1	315	76	143	168	222	247
	2	81	16	33	39	52	58
	3	1088	208	592	452	884	705
	4	328	112	–34	215	17	305
US 29	1	100	–48	–40	–38	–34	–33
Total[a]		2817	271	748	926	1301	1460

[a]US 29 not included.

A sensitivity test was also conducted on the results for different scenarios of increasing parking spaces. The sensitivity analysis tested the combinations of increases of 1 percent and 2 percent annually in truck parking spaces at rest areas and increases of 1 percent and 4 percent annually in truck parking spaces at truck stops. The results indicated that for I-64, I-77, and I-85, if there were an annual increase of 1 percent in commercial truck parking spaces in rest areas and an annual increase of 1 percent in truck parking spaces at truck stops, the truck parking spaces deficiency for the "high" scenario (5 percent increase in truck percentage) in 2020 would be eliminated. Also, for I-66, the results indicated that if there were an annual increase of 3 percent in commercial truck parking spaces in rest areas, the trucks parking spaces deficiency of the "high" scenario in 2020 would be eliminated. On I-95, the results indicated that if there were an annual increase of 1 percent in commercial truck parking spaces in rest areas and an annual increase of 4 percent in truck stops, the trucks parking spaces deficiency of the "high" scenario in 2020 would be eliminated. In addition, the results indicate that there is no need to increase the parking spaces along US 29.

Estimation of Cost to Eliminate Shortfall

Because of the lack of recent data on construction costs for commercial truck parking facilities, the cost information used in this study was from the construction of one truck stop along I-81 and a study done by the Trucking Research Institute.[11] The low average cost per space was about $30,000 (Year 1996$) or $33,862 (Year 2001$), and the high average cost per space was about $86,250 (Year 2001$, including the cost of land, evacuation cost, cost of gravel base and paving, and cost of lights and curbing). Based on the results presented in the previous section, the cost for providing the additional parking spaces to meet the future demand was then estimated and is shown in Tables 22 and 23.

Table 22. Summary of Cost Estimation (in 2001$) by Sections for Different Scenarios in 2010

Road	Sec.	Deficiency in 2010 (1)	Cost $ (Low)*	Cost $ (High)*	Deficiency in 2010 (2)	Cost $ (Low)	Cost $ (High)
I-64	1	–2	0	0	–1	0	0
	2	–6	0	0	12	406,344	1,035,000
	3	3	101,586	258,750	5	169,310	431,250
	4	–3	0	0	2	67,724	172,500
	5	2	67,724	172,500	3	101,586	258,750
I-66	1	0	0	0	0	0	0
	2	10	338,620	862,500	10	338,620	862,500
I-77	1	–19	0	0	–16	0	0
	2	27	914,274	2,328,750	30	1,015,860	2,587,500
I-85	1	–9	0	0	–6	0	0
	2	11	372,482	948,750	13	440,206	1,121,250
I-95	1	143	4,842,266	12,333,750	168	5,688,816	14,490,000
	2	33	1,117,446	2,846,250	39	1,320,618	3,363,750
	3	592	20,046,304	51,060,000	452	15,305,624	38,985,000
	4	–34	0	0	215	7,280,330	18,543,750
Total Cost			27,800,702	70,811,250		32,135,038	81,851,250

Table 23. Summary of Cost Estimation (in 2001$) by Sections for Different Scenarios in 2020

Road	Sec.	Deficiency in 2020 (1)	Cost $ (Low)	Cost $ (High)	Deficiency in 2020 (2)	Cost $ (Low)	Cost $ (High)
I-64	1	0	0	0	1	33,862	0
	2	15	507,930	1,293,750	16	541,792	1,380,000
	3	12	406,344	1,035,000	13	440,206	1,121,250
	4	32	1,083,584	2,760,000	37	1,252,894	3,191,250
	5	12	406,344	1,035,000	13	440,206	1,121,250
I-66	1	0	0	0	0	0	0
	2	12	406,344	1,035,000	13	440,206	1,121,250
I-77	1	–12	0	0	–9	0	0
	2	34	1,151,308	2,932,500	36	1,219,032	3,105,000
I-85	1	0	0	0	2	67,724	172,500
	2	21	711,102	1,811,250	23	778,826	1,983,750
I-95	1	222	7,517,364	19,147,500	247	8,363,914	21,303,750
	2	52	1,760,824	4,485,000	58	1,963,996	5,002,500
	3	884	29,934,008	76,245,000	705	23,872,710	60,806,250
	4	17	575,654	1,466,250	305	10,327,910	26,306,250
Total Cost			39,390,000	113,246,250		49,438,520	126,615,000

DISCUSSION

Although the scope of the project originally included only truck stops with 15 or more parking spaces, this limitation had little or no effect on the results, as only a few truck stops with fewer than 15 parking spaces existed within the 2-mile limit from the highway mainline. Similarly, the restriction of considering only truck stops that were within 2 miles of the highway should have no impact on the results of the survey as commercial truck drivers indicated that they would seldom exceed that distance when looking for a parking facility. Although the data collection procedure was very time-consuming, the procedure gave the opportunity for detailed information to be obtained on the characteristics of commercial truck parking adjacent to the interstate highway system in Virginia.

A major problem associated with this procedure, however, was the need to obtain data on the variation in commercial truck parking (accumulation) as traffic and other independent variables varied. In this study, for example, the models were developed based on commercial truck parking accumulation in half-hour intervals, which required traffic volumes in half-hour intervals as in the Phase I study.[14] The researchers were fortunate to obtain the necessary traffic data for the Phase I study because of a recent traffic study conducted on I-81 in Virginia. Similar detailed data were not available for the other highways in this Phase II study. This problem was overcome by using the daily truck traffic volume in this study. The two scenarios used for the maximum percentage of trucks make it feasible for the decision maker to select either a high or relatively lower truck percentage.

The R-squared values obtained indicate that the models are good prediction tools for commercial truck parking in Virginia. This was also confirmed by the very good fit of the data at truck stops that were not used to develop the models. However, although each model closely fit the data that were not used in developing the model, there is no guarantee that the models will be suitable for parking demand forecasting for interstate highways outside Virginia. The reason is that parking characteristics such as parking duration and locations of the truck stops may be different. The *procedure* used for developing the models can, however, be used outside Virginia.

In the latest FHWA study on commercial truck parking,[11] a demand/supply ratio of 2.16 was obtained for public rest areas in Virginia, which was categorized as "shortage." This demand/supply ratio is much higher than the ratios obtained in this study. Although the ratios for many of the rest areas were higher than 1.0, the maximum was about 1.5. This difference may be due to the additional supply of truck parking spaces by the construction of the rest area at Exit 14 on I-81 after the FHWA study.

Similarly, the demand/supply ratio in the FHWA study for private truck stops in Virginia was 0.8, which was categorized as "surplus." However, in this Phase II study, the demand/ supply ratio for truck stops was 1.07. The reason for this difference may be due to an overestimation of the number of available parking spaces at truck stops in the FHWA study. During the inventory at truck stops, the investigators found that the actual existing number of spaces was less than that reported by the managers of some truck stops. In addition, some parking spaces were smaller than the trucks. In some cases, the type of the parking space layout also reduced the actual supply.

The information relating to Virginia provided in the FHWA study was for the entire state and did not provide any detailed information by highway corridor. For example, the locations of the current deficiency were not identified and no indication was given regarding the future conditions. In contrast, this Phase II study provides detailed parking demand information for different segments on Virginia's interstate corridors.

SUMMARY OF RESULTS

- *Currently, the demand/supply ratio for I-95 is about 1.23.* The parking space shortage in rest areas along I-95 is more serious than in the truck stops. Currently, the demand of commercial truck parking at truck stops exceeds the supply by 14 to 32 percent. If no new parking spaces are provided in the future, the demand/supply ratio will increase to about 1.40 to 1.46 in 2010 and increase to about 1.62 to 1.70 in 2020 (no increase is about equal to a 5 percent increase in truck percentage).

- *Currently, there is no shortfall of parking spaces at the truck stops on I-85.* The shortfall of commercial truck parking spaces at the rest areas along I-85 is about 6 percent. If no new parking spaces are provided in the future, the demand/supply ratio for truck stops and rest areas combined will increase to 1.00 to 1.03 in 2010 and to 1.08 to 1.10 in 2020 (no increase is about equal to a 5 percent increase in truck percentage). This may result in more trucks being parked on the shoulders adjacent to the rest areas.

- *Currently, the parking space shortfall at the two rest areas on I-66 at milepost 48 (EB and WB) is about 24 percent.* If no new parking spaces are provided in the future, the shortfall will increase to about 50 percent in 2010 and more than 50 percent in 2020 for the low scenario.

- *Currently, there is no commercial parking shortfall at truck stops along I-64 and I-77.* This finding does not include the section of I-77 and I-64 that overlaps with I-81 (which was included in Phase I of the study).

- *If no new parking spaces are provided in the future, the demand/supply ratio for large truck parking in 2010 along I-64 will increase to 0.99 for no increase in truck traffic and 1.05 for a 5 percent increase in truck traffic. In 2020, the corresponding increases will be 1.15 and 1.17.*

- *If no new parking spaces are provided in the future, the demand/supply ratio along I-77 will increase to 1.04 to 1.08 in 2010 and to 1.12 to 1.14 in 2020 (no increase is about equal to a 5 percent increase in truck percentage).*

- *Currently, there is no commercial parking shortfall along US 29, and, based on the same parking demand increasing rate on the interstate highways, there will be no commercial parking shortfall in 2010 and 2020.*

CONCLUSIONS

- *Private truck stops provide almost 80 percent of the parking facilities for commercial trucks along the interstate highway system in Virginia. Therefore, developing a short-term or long-term parking improvement plan requires the cooperation of the public and private sectors.*

- *The models developed for estimating the demand for commercial truck parking at truck stops along interstate highways give reasonable results and indicate that if no action is taken, shortfalls of truck parking spaces will occur along several interstate highways in Virginia.*

- *The factors that affect the demand for commercial truck parking include the number and percentage of trucks in the traffic stream, the distance between a truck stop and the mainline, the distance between a truck stop and the nearest truck stop or rest area, and the facilities provided at the truck stop.*

- *If the parking facilities for commercial trucks are not expanded, it is highly probable that more trucks will be parked on the shoulders adjacent to the rest areas.*

- *I-95 within Virginia will have a shortfall exceeding 50 percent of commercial vehicle parking spaces within the next few years if no expansion to commercial truck parking facilities in this corridor is undertaken.*

RECOMMENDATIONS

1. *The Virginia Transportation Research Council should conduct a study to investigate the feasibility and/or necessity of establishing a public/private partnership for the construction of new commercial truck parking facilities adjacent to interstate highways in Virginia.* The results of the study indicate the significant contribution of the private sector in providing commercial truck parking facilities in Virginia. It is therefore apparent that the construction of new commercial truck parking facilities cannot be undertaken solely by the public sector.

2. *The Virginia Transportation Research Council should conduct a detailed study to determine whether any changes should be made to the 2-hour parking limit at rest areas and, if so, under what conditions these changes should be made.* The survey indicated that many truck drivers had a negative position regarding the 2-hour limit. However, it cannot be concluded from the results of this study whether repealing the 2-hour parking limit at rest areas will eliminate the shortfall of spaces. It is likely that the temporary repeal of the 2-hour limit at specific locations where the supply of parking spaces is insufficient could be an operational tool during the construction of additional parking spaces.

3. *The Virginia Department of Transportation should collect data on other factors that affect the demand for truck parking spaces.* The impact of other factors, for example, commodity flow pattern and distribution of terminals, was not considered in developing the models as detailed information on these factors was not available.

4. *The Virginia Transportation Research Council should conduct a study to determine the most appropriate technology for disseminating real-time parking information on the availability of parking spaces*. Although many drivers had some sort of communication device in their truck, the best way to disseminate real time parking information on the availability of parking spaces is not clear.

5. *The Virginia Transportation Research Council should conduct a study to investigate the feasibility of allowing commercial truck parking at some interstate exit ramps.* Factors that should be considered include the geometry (curvature, length, width of shoulders) of the ramp, the time of day parking should be allowed, and the maximum parking duration that should be allowed. Although allowing some commercial truck parking at exit ramps might provide some temporary relief until more parking facilities are provided, such an action might have safety implications.

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