FINAL REPORT

Quantify the Effects of Raising the Minimum Speed on Rural Freeways and the Effects of Restricting the Truck Lanes Only in the Daytime

Volume 2: Safety and Operational Evaluation of Truck Lane Restriction on Interstate 75

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16. Abstract

To reduce conflicts between trucks and smaller vehicles, most highway agencies including the Florida Department of Transportation have implemented various truck restriction strategies. The truck restriction methods employed in various states include restriction by speed, lane, time, or route. This study evaluated safety and operating characteristics of the Interstate 75 corridor in north Florida where trucks are restricted throughout the day from using the inside lane—i.e., lane closest to the median—of the six-lane facility. The field data showed that approximately two thirds of both passenger cars and trucks were traveling within the 10-mph pace that ranged from approximately 70 mph to 80 mph in the corridor that has speed limit of 70 mph. The simulation results showed that there would be no gain in travel times or reduction in delays by rescinding the current policy of restricting trucks from the inside lane for a 24 hour period. In addition, the simulation results revealed that the number of lane changes would increase—predicting the likelihood of increased crashes in the corridor—if all lanes were opened to trucks. It is noteworthy that the review of crashes occurring in the corridor indicated that improper lane change was one of the major contributing causes for the crashes that occurred in this corridor. Based on these results, it was concluded that the current lane restriction policy has positive impacts on safety and operating characteristics in the corridor and should be left in place.

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EXECUTIVE SUMMARY

Introduction

The trend to manufacture larger trucks and smaller passenger cars has resulted into a significant variability between the operational characteristics of the two vehicle types raising concerns for the safety of the traveling public, particularly on high truck volume roadways such as limited access facilities. To reduce conflicts between trucks and smaller vehicles, most highway agencies in the United States, including the Florida Department of Transportation, have implemented various truck restriction strategies. The truck restriction methods employed in various states include restriction by speed, lane, time, or route. Trucks may be restricted not to exceed a specified speed limit, or they may be restricted not to use certain lane(s) all the time or during specified times of the day. In some cases, trucks are prohibited from using a certain route altogether.

While highway agencies implement these restrictions with the aim of improving safety and efficiency of highway travel, occasionally there are concerns from trucking agencies which contend that some of these restrictions are excessive and negatively impact truck travel time and thus profitability of trucking companies. This study was conducted partly to address these concerns on the Interstate 75 corridor where trucks are restricted throughout the day from using the inside lane—i.e., lane closest to the median—of the six-lane facility. A field and simulation analysis of traffic operating characteristics of trucks and passenger cars were conducted to determine differences in speeds and travel times across the corridor under various scenarios of restriction by time-of-day. The study further analyzed crashes that occurred in the study corridor to determine the safety experience associated with the inside lane truck restriction.

Methodology

Interstate 75 is a major north-south Interstate freeway in the United States, originating in Miami, Florida and passing through six states before ending in Sault Ste. Marie, in Ontario, Canada. Interstate 75 is mostly a four-lane highway but there is a six-lane section that stretches for 139 miles from Exit 328 (Florida Turnpike) in the south to Exit 467 (County Road 143) near the Georgia/Florida line. This stretch is primarily rural in character with 23 interchanges spaced approximately eight miles apart. At the suggestion of the Project Manager, only a 54-mile corridor was studied in detail. The portion studied started from Exit 374 (County Road 234) in the south to milepost 428 (between Exit 427 and I-10 interchange) in the north. Traffic operating data including individual vehicle records of speeds and headways were extracted from the telemetered traffic monitoring sites located at mileposts 374 in the southern end of the corridor and milepost 428 in the northern end of the corridor.

In addition to field data collection, the CORSIM Version 5.0 simulation software was used to simulate traffic operations in the corridor. The corridor was simulated using the collected field data on geometrics and vehicle characteristics at various times of the day. The simulation involved determining the effect of travel time and speeds of the simulated corridor for the different scenarios taking into account the traffic volume, vehicle type distribution, time of the day, and other pertinent factors. The effects of these operational factors were analyzed under various scenarios of restricting trucks during the daytime only and 24-hour restriction. Also analyzed were the crashes that occurred in this corridor for a 2-year period from January 1, 1999 to December 31, 2000. The conclusions and recommendations are based on these analyses.

Findings

The following are the major findings of the study based on the field, simulation, and crash data that were analyzed:

- the field data showed that approximately two thirds of both passenger cars and trucks were traveling within the 10-mph pace that ranged from approximately 70 mph to 80 mph in the corridor where the posted speed limit was 70 mph.
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- the simulation results showed no gain in travel times nor a reduction in delays by rescinding the current policy of restricting trucks from the inside lane for a 24 hour period.
- the simulation results revealed that the number of lane changes would increase—predicting the likelihood of increased crashes in the corridor.

- the crash data analysis indicated that improper lane change was one of the major contributing cause for crashes that occurred in this corridor.

Recommendations

The major recommendation of this study is that the current truck restriction policy in this corridor has a positive effect on safety and traffic operating characteristics and therefore should be left in place. Based on the volume data reported herein, lifting the restriction policy at night should not be considered given that the volume of truck traffic remains high at night almost at levels similar to daytime. While the volume of passenger cars decreases at night, significant decrease does not occur until midnight (i.e., 12:00 a.m.) and begins to increase appreciably around 5:00 a.m. Thus, if only a daytime restriction was to be considered for implementation in this corridor, it would be difficult to define the time period—that is, restricting trucks from 5:00 a.m. to 12:00 a.m. appears awkward and may be confusing to truck drivers and possibly more difficult to enforce.

Recommendations for further research include conducting a detailed study on all freeway corridors in Florida, both urban and rural, to determine how different methods of truck restriction affect safety and operating characteristics. The study should involve control sites with no truck restriction. Operating data from both the experimental sites and control sites should be thoroughly analyzed. The study should also analyze a multi-year crash data before and after the truck restriction policy was imposed and should be compared with the before-and-after crash data from the control sites.

CHAPTER 1--INTRODUCTION

1.1 Overview

The trend to manufacture larger trucks and smaller passenger cars has resulted into a significant variability between the operational characteristics of the two vehicle types raising concerns for the safety of the traveling public, particularly on high truck volume roadways such as limited access facilities. Because of their high weight-to-horsepower ratio, large trucks have low capability to accelerate or maintain speed particularly on steep and sustained grades. Thus trucks generally cause formation of long platoons behind them resulting in the reduction of roadway capacity. The dimensions—height, width, and length—of large trucks also cause visibility concerns for both truck and passenger car drivers. For the truck driver, visibility is reduced on both sides and to the rear of the truck. These blind spots greatly increase potential for sideswipe crashes when the truck driver is merging or diverging from a traffic stream. For passenger car drivers, trucks reduce sight distance to traffic signs, horizontal and vertical curves, as well as to traffic incidents on the roadway (Mannering *et al.*, 1993).

Large trucks also create psychological and physical intimidation to other motorists. Psychologically, motorists feel threatened by the closeness of a truck in the adjacent lane since trucks occupy more length and width of a lane than a typical vehicle. A study by the Transportation Research Board (1986) indicated that as passenger car drivers pass wider trucks, they position themselves closer to the pavement edge, which reduces the margin of safety. In addition, when traveling at high speeds, trucks create powerful air disturbances that can cause unsuspecting motorists to lose control of their relatively lightweight automobiles. Moreover, in inclement weather, e.g. rainy, trucks tend to splash water on windscreens of smaller vehicles thus reducing the visibility of drivers in these vehicles.

To reduce conflicts between trucks and smaller vehicles, most highway agencies in the United States have implemented various truck restriction strategies. Wishart and Hoel (1996) reviewed a range of truck restriction methods employed in various states and found that generally trucks are restricted by speed, lane, time, or route. Trucks may be restricted not to exceed a certain speed limit, or they may be restricted not to use certain lane(s) all the time, or they may be restricted not to use certain lanes in certain times of the day. In some cases, trucks are prohibited from using a certain route altogether. While highway agencies implement these restrictions with the aim of improving safety and efficiency of highway travel, occasionally there are concerns from trucking agencies who contend that some of these restrictions are excessive and negatively impact trucks' travel time and thus profitability of trucking companies.

This study was initiated by the Florida Department of Transportation, Office of Traffic Operations with the purpose of conducting a comprehensive review of safety and operating characteristics on of the six-lane corridor of Interstate 75 in North Florida. Currently, trucks are restricted from using the inside lane (the lane closest to the inside) in both directions for a 24-hr period. The truck restriction practice on this stretch of Interstate 75 dates back to August 1998 and was implemented following a Florida Department of Transportation study which showed that a similar truck restriction policy on Interstate 95 in Palm Beach county reduced the number of crashes involving heavy vehicles; however, the same study found that there was no significant reduction in non-truck crashes (Florida Department of Transportation, 1982).

1.2 Purpose and Scope

The purpose of this study was to undertake a comprehensive assessment of the resulting safety and traffic operating characteristics brought about by the 24-hr inside lane restriction policy. Of particular interest was to determine the impact the policy had on truck speeds throughout the day. This was important because it had been suggested in the past that daytime only restriction might be appropriate in this corridor in order to improve truck speeds and travel times during the night. In reviewing traffic operating characteristics data on geometrics and traffic flow were acquired and analyzed. The review of safety operating characteristics involved acquiring and analyzing crash data for year 1999 and 2000.

To analyze the effect of lifting the restricting policy at night, a simulation approach was used. Two scenarios were simulated, (a) operations with inside lane restriction, and (b) operation with all lanes made available for truck use. A number of measures of effectiveness were analyzed and compared with several field attributes. The CORSIM, which stands for CORridor SIMulation, software was used to generate the measures of effectiveness which included the number of lane changes and the resulting travel times for both passenger cars and trucks in the two scenarios.

Following the comprehensive field data review, safety data review, and simulation review, efforts were made to correlate operational attributes to safety attributes in order to predict what would be the impact of lifting the restriction policy or reducing the policy to daytime only. The questions being asked were what are the benefits of the current policy and would those benefits increase or decrease if the current policy is rescinded or implemented in the daytime only? In addition, what are the separate impacts of the policy or the policy change on trucks? Conclusions and recommendations were based on data analysis with these questions under consideration.

1.3 Site Characteristics

The Interstate 75 is a major north-south Interstate freeway in the United States, originating in Miami, Florida and passing through six states before ending in Sault Ste. Marie, in Ontario, Canada. The Interstate 75 is four-lane in some areas but there is a six-lane section that stretches for 139 miles from Exit 328 (Florida Turnpike) in the south to Exit 467 (County road 143) in the north. This stretch is primarily rural in character with 23 interchanges spaced approximately eight miles apart. However, the City of Gainesville is located in the middle of the corridor. Because of the urban nature of the city, there are four interchanges that are closely spaced—approximately three miles apart. At the suggestion of the Project Manager, only a 54-mile corridor was studied in detail. The portion of I-75 studied started from Exit 374 (County road 234) in the south to Milepost 428 (between Exit 427 and I-10 interchange) in the north. The study corridor is in primarily rolling terrain. There are 7-foot by 6-foot signs posted on overhead bridges, inside, and at a truck weighing station. The posted signs read, “TRUCKS WITH 6

WHEELS OR MORE MUST USE 2 RIGHT LANES." Figure 1.1 shows a site location and Figures 1.2 and 1.3 show photographs that were taken within the study area.

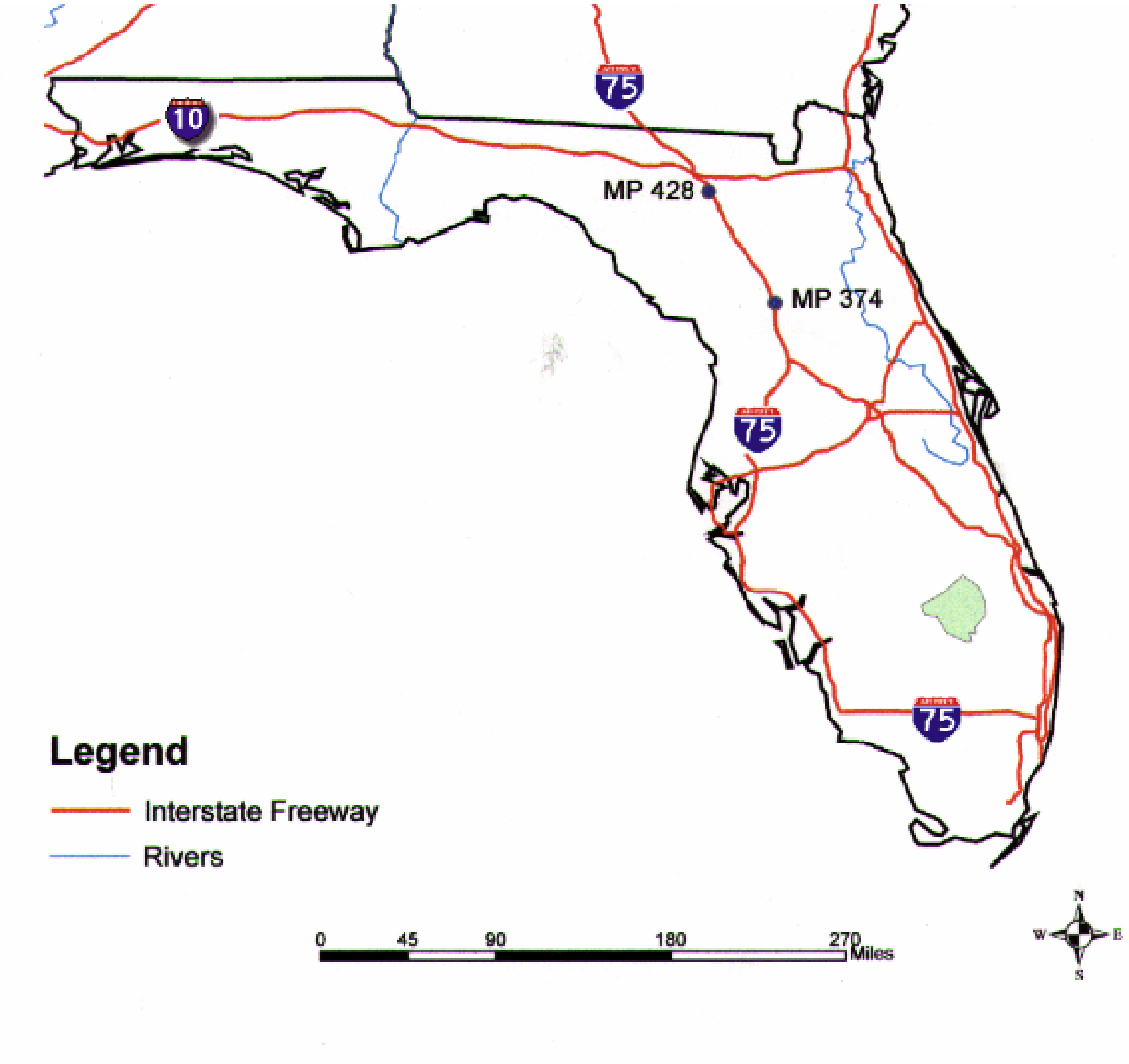

FIGURE 1.1: The Study Corridor

1.4 Methodology

Per scope of services of this project, the first task involved conducting an extensive literature search on published and unpublished information different restriction policies implemented around the country and around the world and summarizing the results of the studies in the literature that evaluated the safety and operating characteristics of the restriction policies in force. A comprehensive search of databases including Transportation Research Information

Service (TRIS), National Technical Information Services (NTIS), Science Direct, Dissertation Abstracts Online, EI Compendex, National Academies, and other databases was performed.

In addition, a detailed questionnaire soliciting information on truck restrictions was synthesized and sent to the relevant State transportation engineers in all 50 states. The questionnaire was devised to gain information on the effects of truck restriction policies implemented in different states on safety and traffic operating characteristics. The purpose of the survey was also to determine circumstances that lead to instituting the truck restriction policy. Another strategy used in gathering information was to conduct a follow-up telephone interview with states that provided relevant information in the questionnaires that were returned.

The second task of the project was to select sites within the corridor for data collection. After conducting numerous runs across the corridor both in the day and night, and after extensive consultation with the FDOT Project Manager, the corridor section that begins from Milepost 374 and ending at Milepost 428 was selected. The whole corridor was driven through at selected times in the day and night to determine site conditions, operating characteristics and to collect data. Speed, headway, volume and travel time characteristics at various locations within the corridor at different times of the day were sampled. However, detailed data were acquired from telemetered traffic monitoring sites (TTMS) available within corridor. These sites are operated and maintained by the Florida Department of Transportation, Planning Office.

In addition to field data collection, the CORSIM Version 5.0 simulation software was used to simulate traffic operations in the corridor. The corridor was simulated using the collected field data on geometrics and vehicle characteristics at various times of the day. The simulation involved determining the effect of travel time and speeds of the simulated corridor for the different scenarios taking into account traffic volume, vehicle type distribution, time of the day, and other pertinent factors. The effects of these operational factors were analyzed under various scenarios of restricting trucks during the daytime only and 24 hours restriction.

As for crash data analysis, the Highway Safety Analysis (HSA) software was used to summarize crash attributes occurring in this corridor. The time frame of crash analysis was a 2-year period from January 1, 1999 to December 31, 2000. The hard copies of police reports of individual crashes were acquired from the Florida Department of Transportation, State Safety Office. The results of the field and simulation analyses were used to guide the making of conclusions and recommendations on this important issue.

CHAPTER 2—REVIEW OF LITERATURE AND CURRENT PRACTICE

2.1 Overview

This chapter reports on the results of the literature search that was conducted to determine what restriction policies exist within and outside Florida and what impacts these policies have on safety and operating characteristics. This study reviewed the current practice on truck restriction to determine the prevailing conditions in other states and the various means of reducing the interaction between trucks and passenger cars. The literature review also focused on the general issues of safety, truck-related crashes, and the effectiveness of various countermeasures implemented on different limited access facilities in the U.S in an effort to increase roadway safety.

A 1993 study by Mannering *et al* showed that two primary concerns exist with large trucks in a traffic stream. First, because of large trucks' operational limitations, motorists and engineers often perceive that trucks restrict the free flow of general traffic, resulting in low speed and accelerating capabilities, longer travel time and headways, and ultimately, an underutilization of the facility. Second, large trucks are thought to present a safety hazard because of decreased stopping capabilities, lack of maneuverability and passing opportunities, and their large size which occupies more roadway space. Trucks thus cause delay to the overall traffic stream and reduces roadway capacity.

The perception that large trucks impede traffic flow is mainly due to the way the operational characteristics of large trucks differ from the operational characteristics of other smaller vehicles. Because of their low weight to horsepower ratio (wt/hp), large trucks have low capability to accelerate, decelerate or maintain speeds compared to passenger cars, especially on sustained grades. The effect of grades on truck accelerating capability is much more pronounced than of passenger cars. The difference, of course, depends on truck type and weight, as well as the traffic volume and the percent of the grade and its length. Trucks generally gain speed by about 5 percent on downgrades and lose speed by about 7 percent on upgrades as compared to their operation on the level grade. On upgrades, the maximum speed that can be maintained by a truck is dependent primarily on the length and steepness of the grade and the truck's weight/power ratio—which is the gross vehicle weight divided by the net engine power. There are other factors that affect the average truck speed on the grade such as the entering speed, the aerodynamics resistance, and the skills of the driver. The latter two factors cause only subtle variations in the average speed (American Association of State Highway and Transportation Officials, 2001). The difference in operating characteristics between trucks and smaller vehicles cause trucks to consistently impede the normal and reasonable movement of traffic and deny passing opportunities resulting in long queues of traffic behind trucks.

The literature also revealed that trucks pose safety problems on freeways. The height, width, and length dimensions of large trucks severely limit the range of vision for both truck driver and surrounding motorists. For the truck driver, visibility is reduced on both sides, and to the rear of the truck. These blind spots greatly increase the risk of a sideswipe crash when the truck driver is merging into the traffic stream, diverging or changing lanes. Trucks traveling next to or in front of other vehicles also reduce the distance at which the motorists can see the exit signs, special warning signs (e.g., "merging lane ahead"), and the unexpected stops. This impairment can lead to dangerous maneuvers that can be avoided only if the motorist has adequate sight distance (Mannering *et al.*, 1993). Figure 2.1 below illustrate the blind spots in which truck drivers can hardly see other vehicles behind, in front, or on adjacent lanes.

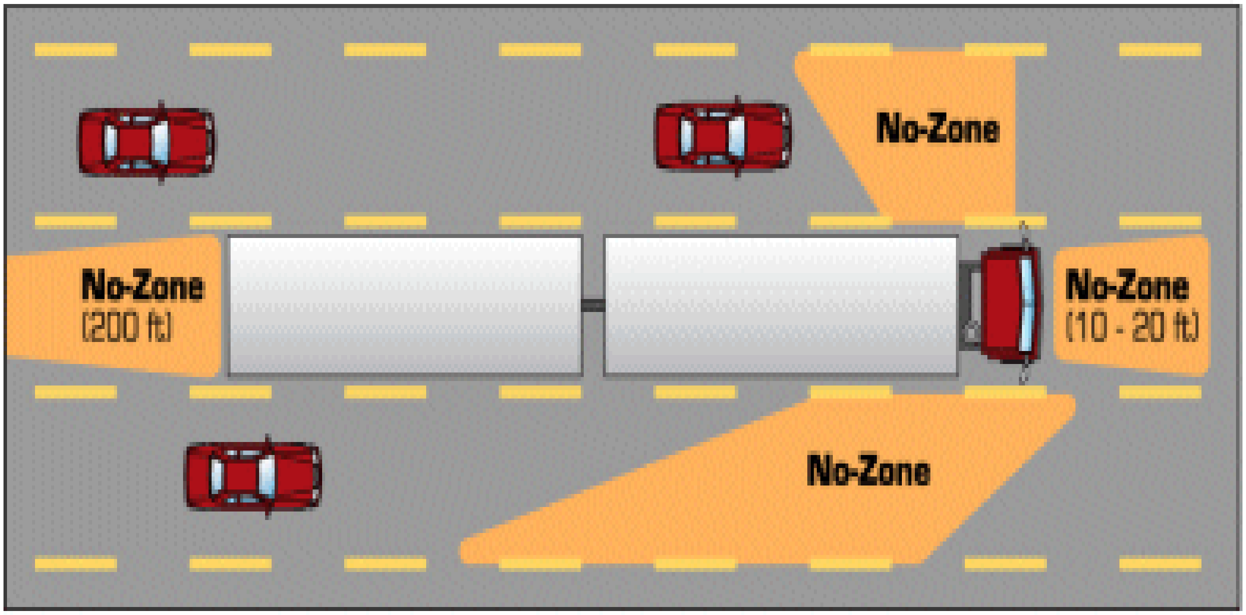

FIGURE 2.1: Illustration of blind spots (no-zone) for trucks

A 1986 study by the Transportation Research Board (TRB, 1986) indicated that lateral placement is another effect of trucks on passenger cars. As passenger cars pass wider trucks, they must be positioned closer to the truck or to the pavement edge, or both, which reduces their margin of safety. In inclement weather and when the visibility is a problem, such as night hours, the situation is likely to worsen. Large trucks also create physical and psychological intimidations to other motorists. Psychologically, motorists feel threatened by the closeness of a truck in the adjacent lane since trucks occupy more length and width of a lane than a typical vehicle. This is becoming an even greater problem because of the trend to manufacture larger trucks and smaller cars. When traveling at high speeds, trucks create powerful air disturbances that can cause unsuspecting motorists to lose control of their relatively lightweight automobiles (Mannering *et al.*, 1993).

It is noteworthy that vehicle types on U.S highways are generally classified based on number of axles or on weight-to-horsepower ratio as shown in Table 2.1. This classification is generally known as "Scheme F" and was developed by the Federal Highway Administration (FHWA). Studies indicate that as the number of axles increase, the weight-to-horsepower ratio also increases (AASHTO, 2001).

TABLE 1.1: Vehicle Classification in the United States

Vehicle Class	Description	No. of Axles
1	Motorcycles	2
2	Cars (includes 1 or 2 axle trailer)	2,3 or 4
3	Pick-ups and vans (includes trailers)	2,3 or 4
4	Buses	2 or 3
5	2-Axle, single unit trucks Dual rear wheel (6-Tire)	2
6	3-Axle, single unit trucks	3
7	4-Axle, Single unit trucks	4
8	2-Axle Tractor, 1-Axle Trailer 3-Axle Tractor, 1-Axle Trailer 2-Axle Tractor, 2-Axle Trailer	3 4 4
9	3-Axle Tractor, 2-Axle Trailer 3-Axle Single unit Truck with 1-Axle Trailer	5 5
10	6 or More Axle Single Trailer Trucks	6 or more
11	5-Axle Multi-Trailer	5
12	6- Axle Multi-Trailer	6
13	7 or More Axle Multi-Trailer Trucks	7 or more

2.2 Trucks' Stability and Operating Characteristics

Stability properties of trucks have an important bearing on the safety of their operations. For example, if a truck is unable to respond quickly in emergency braking situations or if it can't maintain its intended lane or resist overturning while negotiating sharp turns, it is reasonable to assume that the truck is more likely to become involved in a crash than vehicles with better performance. The study by the Transportation Research Board (1986) discussed the handling and stability characteristics most related to safety that are influenced by truck weight, size or articulation as briefly explained in the following subsections.

2.2.1 Trucks Braking Effects

Trucks are unable to quickly respond in emergency braking situations as compared to passenger cars. Trucks are also more likely to experience instability during braking. Truck configuration has a great effect on its braking performance depending on the type of a truck. If a truck has properly designed, maintained, and adjusted brakes it can have almost similar emergency stopping distances and little difference in controllability under emergency braking compared to other vehicle types. However, operating conditions that may become rather prevalent with trucks (especially large trucks with trailers) involves the coupling of an empty trailer behind a full one to facilitate trailer movement between terminals. Under such conditions, the wheels on the empty rear trailer are severely over-braked and controllable braking is hindered (TRB, 1986).

2.2.2 Truck Offtracking

Truck offtracking is a condition in which the paths of the trailing wheels of a turning truck are offset from those of the leading wheels. In a turn at low speed, the paths of the trailing wheels of the offtracking truck are offset inward from those of the leading wheels. In high-speed offtracking, the paths of the trailing wheels of the turning truck are offset outward from those of the leading wheels. Offtracking can cause potentially hazardous encroachment by the rear of a trailer into the lane next to the one it is traveling in, can stimulate disruptive maneuvering by truck driver or other drivers nearby, and can cause stationary roadside objects (e.g. curbs and signs) to be struck (TRB, 1986).

2.2.3 Response to rapid steering, oscillatory sway and stability in steady turns

Large trucks with more than one hitch coupling the rear trailer may exhibit an exaggerated, whiplike response to rapid steering such that rear-trailer rollover results. This whiplike behavior resulting from truck’s rapid evasive steering is referred to as rearward amplification and is one of the important physical features that affect the relative safety and increase the chances of a truck to be involved in a crash (TRB, 1986). Another truck stability characteristic results from oscillation of a truck (or truck sway) in response to minor road disturbances. Truck sway does not affect vehicle control but may distress the driver of the truck or other motorists. The occurrence of sway has been associated with driver inexperience, slack in the hitch connections, improper trailer loading and poorly maintained equipment and is said to be a potential hazard to the extent that other motorists may take anomalous action to avoid operating near a swaying truck. Another most significant truck handling and stability characteristic is its stability in steady turns. When a truck enters a turn at high speed it becomes difficult to control because of a dramatically increased sensitivity to steering. That is, small increments in steering will tend to yield increasingly severe responses. If the control challenge is great enough, the driver may fail to prevent the vehicle from spinning around or running off the road or to unintended lane (TRB, 1986).

2.3 Objectives of Truck Restrictions

The literature search revealed that the overall goal of implementing truck restrictions is to improve highway operations and the level of safety, to provide for more even pavement wear, and to ensure better operation and safety through construction zones while maintaining an adequate level of economic prosperity (Mannering *et al.*, 1993). When properly implemented, truck restrictions can increase the overall operational efficiency of freeways and lead to improved traffic safety on these facilities. A study conducted by Wishart and Hoel (1996) reported that a variety of truck restriction methods have been implemented throughout the United States. Some of these restriction methods use one lane while others use two lanes. Some use the inside lane(s) while others use the outside lane(s). Some use barriers to separate lanes for the exclusive use of trucks. Some use a different speed limit for truck lane(s) while others don’t. In some states there are highways in which lanes are restricted only during certain hours while others operate 24 hours a day.

The 1986 survey of state practices by the Federal Highway Administration (FHWA 1986) identified the most common reasons given by the states for using truck restrictions are: (1) to improve operations (14 states); (2) to reduce accidents (8 states); (3) for pavement structural considerations (7 states); and (4) for restrictions in construction zones (5 states). The report also indicated that there re other minor reasons for truck restriction. For example, the State of Georgia adopted truck restrictions because it was found that trucks were often observed traveling abreast across several lanes on freeways, denying passing opportunities to other vehicles. The Georgia Department of Transportation (DOT) determined through formal review of accidents that trucks were over-involved in weaving and lane–changing crashes (Middleton *et al.*, 1989).

The Florida Department of Transportation conducted a study in 1982 and implemented a truck restriction on I-95 in Broward County with an objective of significantly reducing the level of intimidation and stress among drivers of automobile (FDOT, 1982). Truck restrictions have also been justified with the objective of reducing pavement deteriorations which result from trucks’ repetitive heavy roads. This phenomenon is best described in terms of change in the present serviceability index (PSI). After years of repetitive loads, the pavement reaches terminal serviceability index (TSI) sooner than its normal designed life (Huang, 2004). Thus, enforcing truck restrictions on highways would serve to extend the life of pavement.

Prompted by the desire to achieve these objectives, several states in the U.S have realized the need to implement some type of restrictions on trucks. However, it should be noted that there is no clear consensus on what type of restrictions could be effective in achieving these objectives (Stokes & McCasland, 1984).

2.4 Types of Truck Restrictions

The literature that was reviewed showed that the major types of restrictions imposed on truck travel are by lane, route, speed and time of day. The type of restriction depended mainly on the objective of the restriction and the geometric and traffic characteristics of an area where the restriction is intended to be implemented. The following subsections describe in detail these types of restrictions.

2.4.1 Lane Restriction

Lane restrictions refer to the restriction of all trucks, or trucks of specific size, weight, or axle configuration, from traveling in a specified lane or lanes on the facility. As defined before, trucks can be required to use certain lanes or restricted to use other lanes. On larger facilities, it may be more convenient to specify lanes that trucks are not permitted to use rather than those that they are permitted to use. Prior studies on truck lane restrictions have produced inconsistent results. The effect of restricted lanes on freeway operations apparently differs based on factors unique to each site, such as the way the restriction is used, the traffic characteristics, terrain, and highway geometry in general. For example, one study conducted in Texas (Stokes & McCasland, 1984) revealed that the continuous frontage road design with numerous entrance and exit ramps on the right side of the freeway results in a large number of weaving and merging maneuvers on many Texas freeways. In addition, the study further reported that some of the networks have frequent freeway-to-freeway interchanges and lane drops which force trucks to travel on the extreme left or right lane. As a result, truckers use the center lanes of the freeway. If lane restrictions were applied to the inside or outside lanes, transition areas near interchanges and lane drops would have to be created for trucks to legally travel in the lane.

Stokes & McCasland further reported that restricting trucks to the right lane could block signs on the right side of the freeway. In addition, the pavement might not be able to handle all truckloads in one lane. The study concluded that the restriction of trucks to one lane with mixed traffic does not improve safety and operations, although drivers perceive this to be the case. However, prohibiting trucks from left lane where three or more lanes exist would be beneficial as would restricting trucks to the two rightmost lanes where four or more lanes exist. On the other hand, a simulation analysis of traffic flow elements for restricted truck lanes on Interstate highways in Virginia (Hoel & Peek, 1999) drew several conclusions after observing and analyzing the truck lane restriction on Interstate highways in Virginia:

(i) restricting trucks from the left lanes with steep grades causes an increase in speed differential and decrease in density and the number of lane changes,
(ii) restricting trucks from right lanes cause an increase in number of lane changes which may adversely impact the facility's safety and operation,
(iii) site characteristics dictate the effects of truck lane restrictions, and
(iv) restricting lanes in areas with high proportional of merging and diverging traffic might not be safe for traffic operations.

In general, the Hoel & Peek study recommended that trucks be restricted from the left lane when grades are 4 percent or greater. The study further recommended that trucks should not be restricted from using the right lane. The study did not support the removal of truck lane restrictions in the sites that were studied and explained that most restrictions applied to facilities with a minimum of two lanes in each direction. However, a number of states limit the use of truck lane restrictions to larger facilities that have at least three lanes in each direction.

Table A-1 in Appendix A summarizes the common practices throughout the U.S regarding lane restriction. Two main types of the lane restrictions exist throughout the country. The first restricts trucks from using the left lane (s) and the second restrict trucks from traveling in the right lane (s). Lane restrictions are either site-specific or statewide depending on the objective of restriction and justification of its use. The lane restrictions are also implemented on a mandatory or voluntary basis. Site-specific lane restrictions are those that are suitable for a specific site, for example, areas with grades where trucks cannot maintain speeds or where there are unusual safety concerns. In some States, lane restriction is voluntary; for example, in Arkansas and Nevada signs were posted requesting all trucks to use the extreme left lane which later became the statewide practice along all the Interstate highways running through the states. With an exception of few states, mandatory restrictions are the most prevalent type of restriction in the U.S. There are some variations in the truck types specified under the restrictions. In some cases, all trucks are restricted while sometimes truck specifications are measured by weight which usually includes vehicles with a 10,000-lb minimum gross vehicle weight. In other cases, trucks are restricted in terms of number of axles in the truck configuration, which usually includes trucks with a minimum of three axles. To improve operation or safety on the facility, trucks in U.S are most often restricted from traveling in the extreme left lanes because it is generally accepted that the left-lane is the high-speed lane frequently used as a passing lane.

2.4.2 Route Restrictions

Route restrictions involve restricting all trucks, or trucks of specific size, weight, or axle configuration, from traveling on certain routes. Contrary to truck lane restrictions which are implemented to improve the interaction of trucks with other vehicles by limiting the lanes of travel for trucks, route restrictions remove trucks altogether from the traffic stream in certain areas. There are two basic types of truck routes discussed in the literature. The first includes the designation of bypass and business routes. The primary intent of this designation is to direct through trucks to the best available route. Trucks are directed to routes that bypass areas of intense congestion. Truckers are required to enter an urban area and travel to any side of that urban area without being routed to areas of heavy traffic congestion. Also, trucks are some times restricted from passing through residential areas for safety reasons.

The second type of truck route is designed to guide trucks along specific roadways to downtown areas, industrial facilities or major commercial areas. Such restriction concentrate truck volumes onto roadways designed and constructed to serve heavier vehicles. It has been shown by prior studies that little effort has been made to quantify the effectiveness of route restrictions. But because the efficient routing of trucks would certainly include the freeway system, route restrictions would probably have little effect on freeway safety and operations (Stokes & McCasland, 1984). An example of a truck route sign is shown below.

FIGURE 2.2: A sign instructing trucks not to use a particular route

2.4.3 Time-Of-Day Restrictions

In time-of-day restrictions all trucks, or trucks of a specific size, weight, or axle configuration are restricted from specific lanes or specific routes at specified times of the day, usually during peak hours. Time-of-day-restrictions prevent truckers from driving during those times of day when traffic congestion is at its highest level so as to improve traffic operational characteristics during these congested time periods. In some states—for example, Arizona and Minnesota—trucks are permitted to use a particular facility only during daylight hours. Other states restrict trucks at different time periods in terms of speed. For instance, in Texas the posted speed for trucks during the daytime is 60 mph which is reduced to 55 mph during nighttime (Mannering *et al.*, 1993).

A study conducted in Texas by Stokes & McCasland (1984) revealed that traffic volumes on freeways tend to peak at time periods between the typical morning and afternoon commuter peaks. Prohibiting trucks on the freeway during commuter peaks may produce only marginal improvements in the freeway traffic flow. Given the latent travel demands that exist for many urban freeways in Texas, removing trucks from the freeway during peak periods probably would not significantly reduce peak period traffic volumes. Even if latent travel demands could be disregarded, prohibiting trucks during the commuter peaks would probably reduce peak period traffic by only 5 percent. On the other hand, results from the 1975 Urban Mass Transit Association study conducted by Kearney (1975) showed that a complete restriction of truck traffic on urban freeways during daylight hours could potentially increase average network speeds by about 10 mph during the peak hours.

The specific implications of time of the day restrictions seem to differ and difficult to precisely quantify and the road safety benefits also appear somewhat questionable. For example, truck crashes (like truck traffic) tend to take place during off-peak time periods. The fact that off-peak period operating speeds are generally much higher than peak-period suggests that the real problem may be speed (Stokes & McCasland, 1984). The literature review seems to suggest that time-of-day restriction has pitfalls and it requires careful consideration before being implemented. For example, prohibiting trucks on the freeway not to use certain routes may merely divert truck traffic to other routes that, because of their low design standards, are less suited to truck traffic than the freeway. Additionally, prohibiting trucks during certain time periods may divert them to other less-congested time periods, conceivably producing an overall increase in the number of truck-related crashes (Stokes & McCasland, 1984). This suggests that restricting trucks during the daytime only may attract more trucks to travel during the nighttime, if the volume of traffic at night is not low enough to allow adequate passing opportunities and maneuverability or high enough to restrict overspeeding, truck-related and overall crashes may be increased.

Time-of-day restriction practices in different states are shown in Appendix A, Table A-2. Time-of-day restrictions apply mainly to oversize/overweight trucks. To maintain an adequate level of safety and improve operation slower oversize/overweight trucks are required to travel only during daylight hours or prohibited on the facilities during peak periods (Mannering *et al*., 1993).

2.4.4 Speed Restrictions

Speed restriction is the restriction where all trucks, or trucks of a specific size, weight, or axle configuration are restricted to traveling at lower speeds than the rest of the traffic stream or all vehicles are restricted to reduce their speed or forced to adhere to the posted speed limit. Excessive speed is cited in different studies as the primary cause of traffic crashes and particularly critical for large vehicles (Mannering *et al.*, 1993; Wishart & Hoel, 1996). The condition becomes worse when excessive speed is coupled with trucks' problems of stopping distance and lane-changing maneuvers in heavy traffic. Generally, there are three types of speed restrictions: (1) reduced speed limits for all vehicles, (2) reduced speed limits for trucks only, and (3) strict enforcement of existing speed limits for all vehicles. Since most truck crashes are reported to occur during off-peak periods when speeds are high, a speed reduction for all vehicles can result in a reduction in total crashes as well as truck crashes. The alternative of reducing truck speed limits only is complicated since differential speed limits could likely increase crashes occurrence but it is also true that a lower speed limit for trucks on congested urban freeways may be an effective means of reducing conflicts (Stokes & McCasland, 1984).

Following the establishment of the 55 mph speed limit, the proportion of crashes in which heavy trucks rearended autos increased (Zaremba & Ginsberg, 1977). The total number of traffic crashes, however, did decrease. The increase in the proportion of rear-end crashes suggests that truck speeds had not decreased as much as auto speeds and implied that the problem may be one of enforcing existing speed limits, not imposing additional (or differential) speed restrictions. Although no formal studies deal with the effectiveness of speed restrictions, speed regulations seem to offer the greatest potential for reducing crashes. However, previous studies have found that speed differential results in an increased incidence of crashes. Hence instituting differential speed limits has generally been discouraged and many transportation professionals feel it may in fact pose a safety hazard. Only twelve states shown on Appendix A, Table A-3 are currently imposing differential speed limits for cars and trucks. The speed limits differ by either 5 mph or 10 mph, with truck speed always being lower (Mannering *et al.*, 1993).

FIGURE 2.3: Truck speed restriction in Montana in late 1990s

2.5 Evaluation of Traffic Operations on Truck Restricted Roadways

Operating speeds and the difference in speeds between trucks and passenger cars are among the essential traffic characteristics that have been discussed in the literature. By 1986, the speed differential between large trucks and other vehicles had been reduced as a result of the 55-mph speed limit, continual improvements to highways, and the use of high-powered engine trucks (TRB, 1986). Nevertheless, large trucks continue to travel more slowly than other traffic on severe grades, which suppress the average travel speed, increase the average travel time and delays, intensifying passing requirements and increase the risk of crashes. Sometimes the truck speed seems not to differ substantially from those of passenger cars, the real concern of truck speed on highways, however, focuses on whether trucks will be able to maneuver and take evasive action when conditions require. So the speeds may not differ substantially but performance capabilities of trucks and passenger cars do. Generally, speed of trucks on level sections of highway approximates the average speed of cars but they differ on the grades depending primarily on length and steepness of the grade, tractive effort and weight-to-horsepower ratio, which is the gross vehicle weight divided by engine horse power (AASHTO, 2001).

Mannering *et al.* (1993) evaluated truck restriction in Puget Sound region in the State of Washington. The before and after lane restriction evaluation revealed a statistically significant increase in average speed for both trucks and passenger cars after the implementation of truck lane restriction. However, the increase in speed for both vehicle types was less than 4 percent. The speed changes were examined on each lane to be assured whether this increase is attributable to the lane restriction. In each of the four lanes there was a potential increase of speed after restriction for both trucks and passenger cars except on one lane. The reason for no change of speed on one lane was said to be road grade and operational limitations. Trucks on the lane had already been traveling at their peak operational speed before the implementation of the truck restriction, because of geometric and operational constraints the peak speed could not increase regardless of any improvements to facility operation.

There was also a change in average speed violation rates that were determined by measuring hourly distributions per lane for both trucks and non-trucks. An overall increase in speed was accompanied by an increase in speed violation rates for all vehicles after implementation of lane restriction. However percentage of trucks and passenger car violating the speed limit varied throughout the day as the traffic volumes varied depending on time of a day, speed decreased as the facility approached capacity. Speed decreases with increase in volume but sometimes higher volume may restrict maneuverability and not necessarily speed, this results into increased safety risk.

Another study done on Interstate highways in Virginia argues that the implementation of truck lane restrictions could increase the speed difference since cars may be able to travel faster when not impeded by trucks and truck speeds might decrease because of lane restrictions (Hoel & Peek, 1996). Thus, speed differential between trucks and other vehicles is one of the significant operational variables and serves as a measure of the extent of operational effects between cars and trucks on the highway.

Availability of passing opportunities is among the traffic characteristics that are closely observed on the truck lanes. The reduced speeds of large trucks on grades increase the number of overtakings by higher performance vehicles. Safety can be diminished because of braking by other vehicles to reduce their speed and the increased risk associated with passing maneuvers. On multilane highways, opportunities to pass are frequent except under severe congestion, and the lane-change maneuver entails little risk in comparison to two-lane, two-way highways. On the other hand, passing a truck is inherently more risky, and the degree of risk is influenced by truck size. The width of the truck restrict the site distance of trailing motorists, and a long truck increase the distance and time during which the passing vehicle is at greatest risk (TRB, 1986).

2.6 Evaluation of Safety on Truck Restricted Roadways

Although truck performance and traffic operations studies are useful, the evaluation of historical crash patterns is essential for ascertaining the influence of large trucks on highway safety. The number and severity of crashes are definitive measures of safety. The issue of truck crashes on highways is a vital concern for both traffic managers and the general public. Truck restrictions are considered as one of the countermeasures to reduce crashes but in some of the crashes analysis undertaken, little change in crashes experience was noted. The truck restriction evaluation in Puget Sound characterized the level of safety for a particular facility by examining the distribution of crashes across the facility, the types of crashes that are occurring, and the severity of the crashes (Mannering *et al.*, 1993). Crash severity was examined at three levels: crashes resulting in property damage only, crashes resulting in injury, and fatal crashes. The majority of the crashes studied resulted from a vehicle moving straight ahead and sideswiping another vehicle, changing lanes, or merging from an on- ramp. Also, the predominant vehicle type (truck or passenger car) that initiated the crash was considered. In most cases, any noted increase in the number of crashes was more likely attributable to an overall growth in general traffic including truck traffic and not the restriction.

The Florida Department of Transportation analyzed the effects of truck restrictions on crashes involving trucks and passenger cars (FDOT, 1982). A 25-mile section of the highway with three lanes on each direction on I-95 was analyzed in Broward County. Trucks with three or more axles were restricted from using the left lane from 7 a.m. to 7 p.m. Another site in Palm Beach County without any restriction was used as a control site. Nine years of crash data were used and statistical test was performed to determine differences in crashes before and after lane restrictions. The results of this 1982 study show that a high level of truck driver compliance, i.e. 98 percent, was achieved. In comparison to the Palm Beach County, the truck lane restriction reduced the number of truck crashes by 38 percent and the number of truck injury crashes by 57 percent. Crashes involving all vehicles decreased by 2.5 percent for a 24-hour period while crash rate during the restriction period rose by 6.3 percent. However, since the proportion of crashes involving trucks decreased by 3.3 percent during restriction hours, lane restriction was recommended as an effective countermeasure to reduce crashes.

A simulation study was conducted by Garber & Gadiraju (1990) to determine the effects of truck restrictions on traffic flow and safety. The objectives of the study were to determine speed-flow relationships for different traffic lanes at different locations, to investigate the relationship between congestion and crash rates, to determine the effects of strategies on speed and flow distributions, and to investigate the effects of lane-use restrictions on crash rates and time headways. Spot speeds and volume counts were collected in the study from nine locations with 5 to 40 percent truck traffic. A 3-mile section of highway was simulated using SIMAN software package. The restriction that limited trucks to specific lanes on the highway and one that lowered the speed limit for the trucks were combined to create 10 strategies, with only 2 strategies investigating the impact of truck restrictions without a differential speed limit. The results of the study indicated that restricting trucks to the right lane decreased headways in the right lane at some sites. However the study concluded that there were no safety benefits from any of the strategies. Instead there was a potential for increased total crash rates with the implementation of each strategy, particularly on highways with high annual average daily traffic and high trucks percentage.

Stokes and McCasland (1984) evaluated freeways in Houston, San Antonio, and Dallas/Fort Worth in Texas. The study focused on the impact of six truck regulations that could be used to improve safety and operations on freeways in Texas. Trucks accounted for about 3 to 6 percent of total weekday traffic volumes with truck volume peaking from 9 a.m. to 11 a.m. The results of the study indicated that truck speeds were not different from car speeds and the middle lane carried the highest amount of truck traffic. There were many weaving movements because of frontage roads and because of frequent lane drops, trucks did not usually travel in the far left or far right lanes. 33 percent of truck-related crashes occurred in the middle lane, 56 percent in the outside lane or on the ramp and outside. The study concluded that the restriction of trucks to one lane with mixed traffic does not improve safety.

Truck lane restrictions were also implemented on Capital Beltway (I-95 and I-495) in Virginia after a major truck crash (Middleton *et al.*, 1989). The beltway had four lanes in each direction. All trucks were restricted from using the left lane and trucks carrying hazardous materials were restricted to the two rightmost lanes. Crash data were collected for two years before and two years after implementation and compared. The study results showed that the total crash rate increased by 13.8 percent following the implementation of the restrictions. However since the severity of the crashes did not change, it was recommended that restrictions remain in place.

Zavoina *et al.* (1991) examined the restriction of trucks to increase the operational and safety performance of I-20 in Fort Worth-Weatherford, Texas. Engineers and highway users felt that large trucks impede the free flow capability of other vehicles. Three operational characteristics—i.e., speed, time gaps, and vehicle classification—were examined before and after implementation of the left lane truck restriction. The study site comprised of a 9-mile section of a six-lane, two-way rural Interstate on I-20 between Fort Worth and Weatherford. The study showed that after the restriction was in place, only 3 percent of trucks traveled in the left lane, whereas the distribution of other vehicles remained the same. The authors concluded that truck restrictions have the potential to improve capacity and safety, but since the study involved little truck traffic, these results should apply only to low-volume roadways.

Kostyniuk *et al.* (2002) conducted a study to identify unsafe driver actions that lead to fatal car-truck crashes. The study found that driver factors are equally likely to be recorded for fatal car-truck crashes as for fatal car-car crashes. The study suggested that this may be due to the fact that drivers who get involved in fatal crashes drive in the same manner around trucks as they do around other cars. Five of the equally likely contributing factors were failing to maintain lane, failing to yield right-of way, driving too fast for conditions, exceeding speed limit, failing to obey traffic control devices, and inattentive driver. The aforementioned factors comprised approximately 65 percent of reported driver violation behaviors. Four factors were found to be more likely to occur in fatal car-truck crashes than in fatal car-car crashes. These factors are following improperly, obscured vision, drowsy or fatigued driving, and improper lane changing. However, these four factors were recorded for only about 5 percent of the car-truck crashes.

2.7 Enforcement and Regulatory Practices

The effectiveness of any truck restriction or regulation depends on the extent to which those affected comply with the stipulations of the regulation. Consequently, for a restriction or regulation to be effective it must be enforced (Stokes & McCasland, 1984). Enforcement should be the primary issue in assessing the potential effectiveness of the restrictions. The restrictions directed at prohibiting or limiting truck usage of freeways would be difficult to enforce, however, increased enforcement of existing regulations appears to offer the greatest potential for improving freeway safety. The reduction in freeway crashes that could be realized from more stringent enforcement of existing truck regulations can also have positive traffic flow benefits. The regulations should not only be enforceable but also realistic and favorable to facility users (Stokes & McCasland, 1984). For example, applying lane restrictions at times of day that might not be convenient, e.g., at off-peak or night hours when traffic volumes are probably low and opportunities to pass are plentiful, might erode the support and compliance of the regulation by a group of road users. Most lane restrictions operate 24 hours a day to ease enforcement efforts and motorist confusion. Florida is one of the exceptions in that the site-specific restriction on I-95 prohibits trucks with three or more axles from using the left lane between 7 a.m. and 7 p.m. (FDOT, 1982).

Facility design may greatly inhibit the enforcement of the restricted lane. A facility where trucks are not allowed to use the left lane must have adequate outside space on the left-hand side to allow the enforcement officer to pull over large trucks and cite them safely without disrupting the normal flow of traffic (Mannering *et al.*, 1993). It is not feasible, especially in urban areas with high traffic volumes, to pull over the violators to the righthand side of the roadway. This would not only affect the efficient operation of the facility but also decrease motorists' level of safety because of the trucks changing lanes. Having police visible at the restriction site, at least in the initial implementation stage, may be adequate and would predictably reduce weaving and speeding, even if physical enforcement is impossible.

A 1986 study by Stokes & McCasland documented truck operations and regulations on urban freeways in Texas explaining the same point of how the enforcement efforts may be hampered by the facility design. The authors insisted that the road design with numerous entrance and exit ramps on the side of the freeway, frequent freeway-to-freeway interchanges, and lane drops would require trucks not to travel on the extreme outside lanes. Implementing an inside or outside lane restriction for trucks would require transition areas to be established before and after lane drops so that trucks could travel in other lanes in the vicinity of lane drops. Narrowing the roadway cross section at lane drops obviously requires traffic in the affected lane(s) to switch lanes. If truck traffic were restricted to the left or right most lanes, lane changes would be concentrated in a short and constricted section of the freeway, the necessity for transition areas in the vicinity of lane drops would certainly add to the difficulty associated with lane use restrictions in general. Alternatively, trucks would have been prohibited in the outside lane, except to exit or immediately following entry to the freeway but this would require the establishment of areas in the vicinity of interchanges in which trucks would legally travel in the outside lane of the freeway. Defining and enforcing the limits of these areas could pose serious problems.

The literature reviewed emphasized that lack of professional truck drivers is another issue that needs paying attention to as far as the regulatory practices are concerned. More stringent licensing, training, and monitoring procedures could do much to improve the safety of truck operations, especially on urban freeways (Stokes & McCasland, 1984). Unqualified drivers should be ruled out with the requirement that drivers take the test in a vehicle or vehicle combination that is at least somewhat comparable to the vehicle that the applicant will be driving. For instance, a would-be truck driver should not take a test in single unit truck and then drive on the road in a tractor-trailer. However, those already licensed and don’t qualify will continue to drive without further evaluation. Enforcement of many of the provisions of the new laws and strategies remains in question. Experience with nonseparated, concurrent flow, high-occupancy vehicle lanes is a vivid example that shows how general lane restrictions are virtually unenforceable, particularly during peak periods. Stokes & McCasland (1984) argued that despite of all the evidence that strongly suggested a direct relationship between the presence of law enforcement personnel and traffic law compliance rate, it can’t be stated categorically that increased law enforcement has a positive safety value. However enforcement of existing regulations is highly recommended.

2.8 Summary of Literature Review

Prior experience with various truck restrictive measures has revealed inconsistent results. Based on the literature, the effect of different truck restrictions on freeways operations and safety apparently differs depending on factors unique to each site, such as type of restriction used, traffic characteristics, traffic volume and composition, geometric design and terrain. However, beneficial results were reported for most sites because of truck restrictions and their potential to increase safety and capacity. Among the major factors that affect traffic operation and safety on the freeways is the overall traffic volume and truck percentage. Since these factors are not uniform throughout the day, their effect on safety and operations depend on time of the day. There is also a need to analyze both congested and uncongested time periods because during uncongested periods most vehicles tend to increase their speed, if this is coupled with increase of unrestricted truck percentage on freeways may reduce facilities level of safety. Analysis of operations and safety of truck restrictions should not rely on the prevailing real-life situation only. Simulation analysis can be conducted using different truck volumes since the volume will be redistributed at different times of the day depending on the restriction policy.

CHAPTER 3—ANALYSIS OF TRAFFIC OPERATING CHARACTERISTICS

3.1 Traffic Volume Analysis

Traffic volume is the number of vehicles passing a point during the specified time period generally expressed as the total number of vehicles for the period, or as an equivalent rate of vehicles per hour. Traffic intensity can portray a realistic performance of the traffic stream. In addition, traffic volume is the prime determinant of the most operational and safety measures on the corridor The interspersion of trucks and passenger cars and the influence of each vehicle type on the overall operational performance—usually measured in travel time, speed, headway, density, number of lane changes etc.—depends on the volume or composition of each vehicle type on the freeway. It is generally accepted that higher volumes of traffic and higher percentage of trucks in the traffic stream cause conflicts that impact safety and operational performance of a facility. As the headway between vehicles decreases—a phenomenon associated with high traffic volumes in congested periods—the lead vehicle will have a negative impact on the following vehicles. For example, when vehicles are closely spaced, the following vehicle can only travel as fast as the vehicle it is following unless the driver of the vehicle has an opportunity and is willing to change lanes. This generally results into decreased speeds, increased travel times, and increased number of lane changes in the traffic stream especially during the congested times of the day.

The volume data for this study were extracted from telemetered traffic monitoring sites located at mileposts 374 and 428, in the southern end and northern end of the study area, respectively. The average hourly weekday traffic and average hourly weekend traffic data for the whole year 2001 were analyzed. The plot of average hourly volumes for weekdays and weekends showed a similar pattern of peaking although weekends had more traffic than weekdays in both northbound and southbound directions. Because of similarities in volume distribution between weekends and weekdays, a typical weekday was picked for further analysis of traffic characteristics. Figure 1 shows the average hourly volumes of passenger cars and trucks for Tuesday, April 30, 2002 downloaded from the telemetered traffic monitoring site at milepost 374.

The data in Figure 1 show that in the southbound direction truck volumes are more evenly distributed throughout the day with a slightly noticeable peak volume of about 340 trucks per hour from 9:00 a.m. to 10.00 a.m. The passenger car volume is relatively high and it peaks around 3:00 p.m. to 4:00 p.m. at 2,600 passenger car per hour (pcph). In the northbound direction, the volume of trucks is slightly higher while the volume of passenger cars is lower compared to the traffic volume in the southbound direction. There is a coincidence of peak hours for trucks and passenger cars in the northbound direction, which takes place between 10:00 a.m. and 11:00 a.m. with a peak hour volume of 520 and 1,880 for trucks and passenger cars, respectively. It is noteworthy that the traffic data analyzed was already summarized in hourly volumes and thus the peak hour factor (PHF), as measure of traffic congestion, could not be calculated. However, the capacity analysis of 24-hr data in both northbound and southbound directions for weekends and weekdays showed that the level of service (LOS) in this corridor was not less than LOS B.

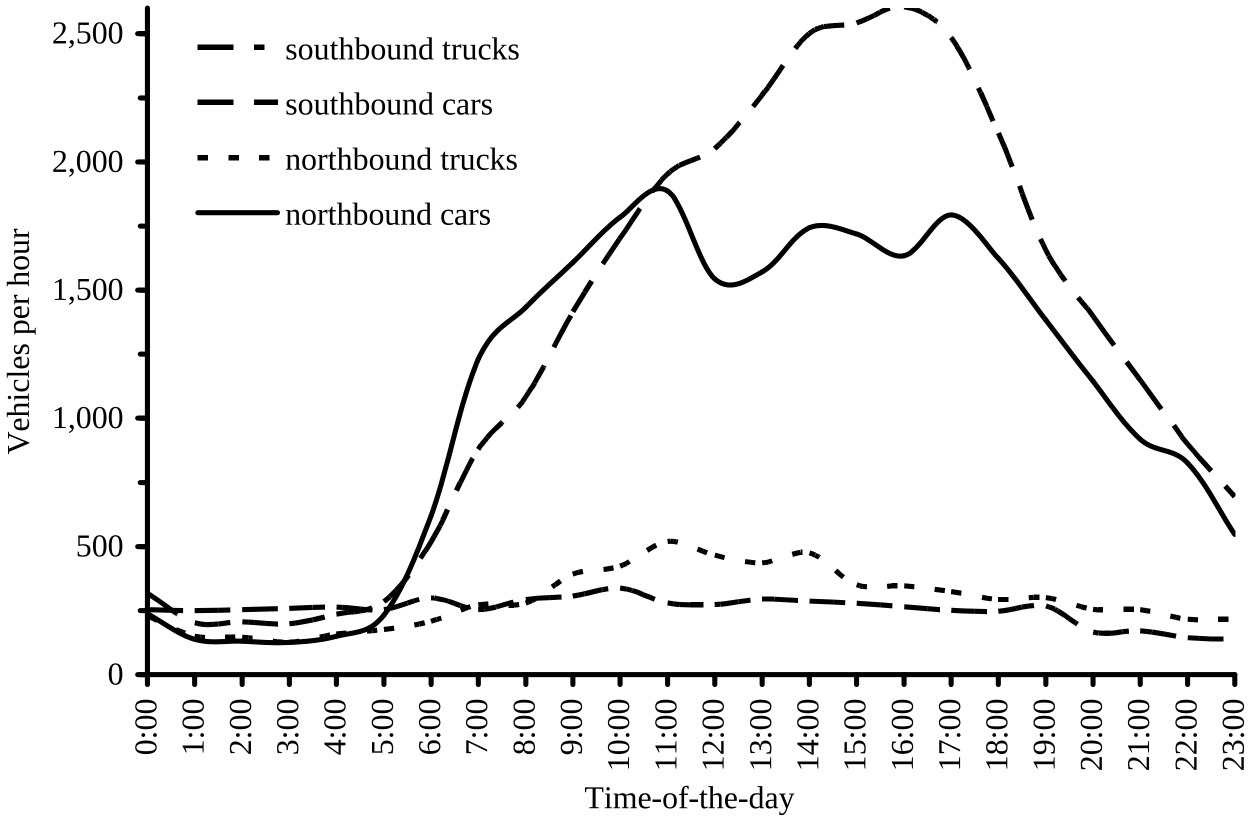

FIGURE 3.1: Hourly Variation of Traffic at MP 374

The data further showed that on the average 29, 47, and 24 percent of passenger cars that were recorded were traveling in the inside, middle, and outside lanes, respectively. Also, 1, 41, and 58 percent of trucks that were recorded were traveling in the inside, middle, and outside lanes, respectively. The 1 percent of heavy vehicles recorded in the inside lane in violation of the truck restriction policy were distributed as follows: 64% were Class 5 vehicles (2-axle single unit trucks, dual rear wheel), 5% were Class 6 (3-axle single unit trucks), and 31% were Class 8 and 9 which are a combination of tractor-trailers and a 3-axle single unit truck pulling a 2-axle trailer.

Those opposed to the 24-hr truck restriction have argued that the restriction be lifted at night, purportedly when traffic volumes are low. It is thus plausible to analyze nighttime conditions in this corridor. Figure 1 shows that the volume of truck traffic remains high at night almost at levels similar to daytime. While the volume of passenger cars decreases at night, significant decrease does not happen until midnight (i.e., 12:00 a.m.) and begins to increase appreciably at around 5:00 a.m. Based on the data in Figure 3.1, if daytime only restriction was to be considered for implementation in this corridor, it would be difficult to define the daytime—that is, restricting from 5:00 a.m. to 12:00 a.m. looks awkward and would be confusing to truck drivers and would possibly be difficult to enforce. In addition, safety implications of such strategy need to be analyzed using field headway data as well as by simulation as reported later on.

Figure 3.2 shows the distribution of traffic data downloaded from the telemetered traffic monitoring site located at Milepost 428 in the northern end of the study corridor. The analysis of data from this site reveals trends similar to those observed at milepost 374. Moreover, data were collected manually at various other sites within the study corridor. The sampled data further showed minimal variation of traffic characteristics and it can be surmised that the trends from these sampled data are similar to those shown in Figures 3.1 and 3.2. This suggests that the majority of traffic in this I-75 corridor is primarily through traffic with a very small proportion of vehicles entering or exiting the freeway at the 10 interchanges located in the study corridor.

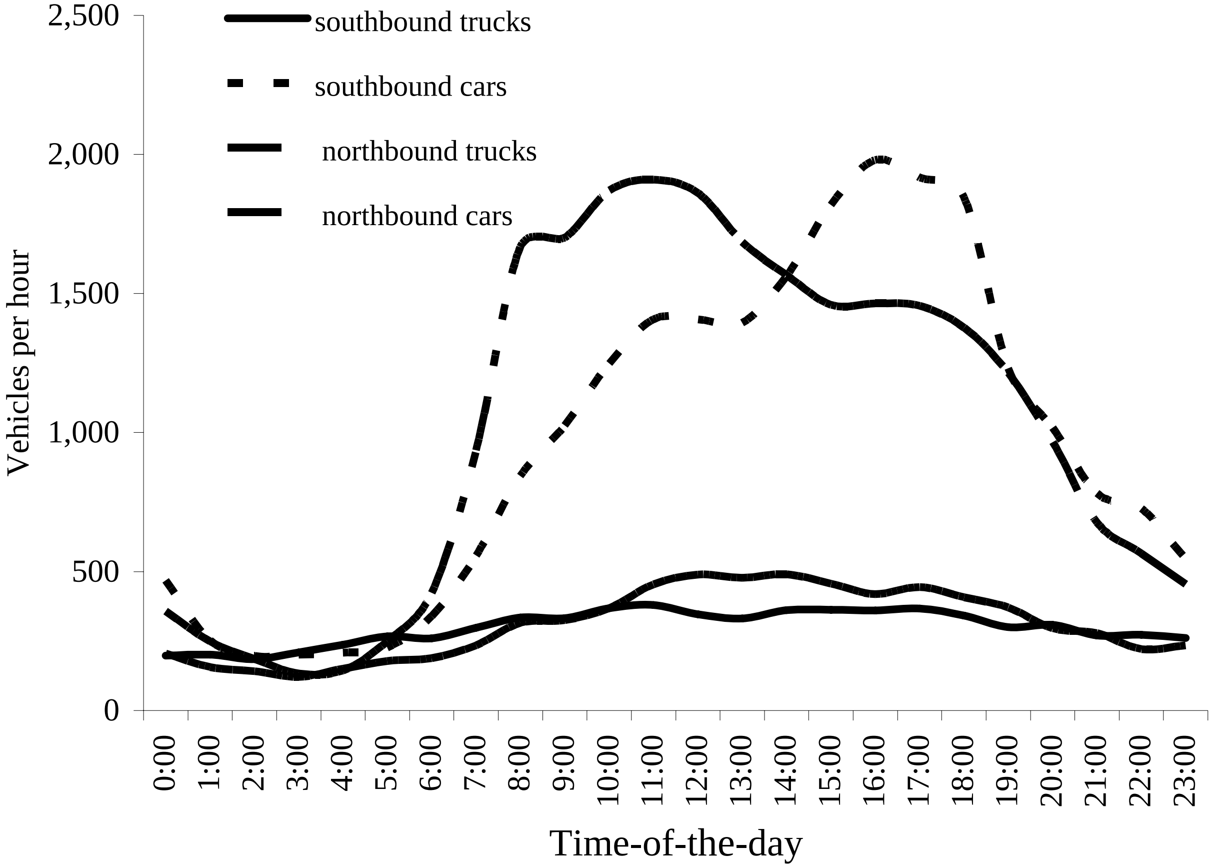

FIGURE 3.2: Hourly variation of traffic at Milepost 428

3.2 Headway Analysis

There are various factors that affect time headway between vehicles some of which are deterministic—e.g., travel speed, volume, vehicle classification—while other factors are random—e.g., driver behavior and weather. Various studies of car following phenomena indicate that lane changing and passing decision are primarily made based on the distance headway between the lead vehicle and the following vehicle in the target lane. Headway is not only a good measure of congestion and lack of passing opportunities created by mixed traffic, it is also a good measure of safety as lane changing and frequent passing generally lead to conflicts and likelihood of crashes.

A lane by lane analysis of headways was conducted to determine the average values and their distribution. Four types of prevailing headways were analyzed: car following car (C→C), car following truck (C→T), truck following car (T→C), and truck following truck (T→T). The hourly averages of these headways were calculated and plotted for each lane. The graphical analysis of these four headway types showed that they follow a trend similar to the volume trend shown in Figure 3.1 and Figure 3.2. At low traffic flow levels the average headways were high and at high traffic volumes the average headways were low. To determine availability of passing opportunities for trucks, headways were analyzed when truck volume is at the highest level, which was from 9:00 a.m. to 10:00 a.m. It was hypothesized that this is the period when truck drivers might feel impeded on the outside lane and would try to pass slow moving vehicles by moving into the middle lane. Thus the availability of passing gaps in the middle lane was analyzed during the truck peak hour. The cumulative distributions of the gaps at mileposts 374 and 428 are shown in Figures 3.3 and Figure 3.4, respectively.

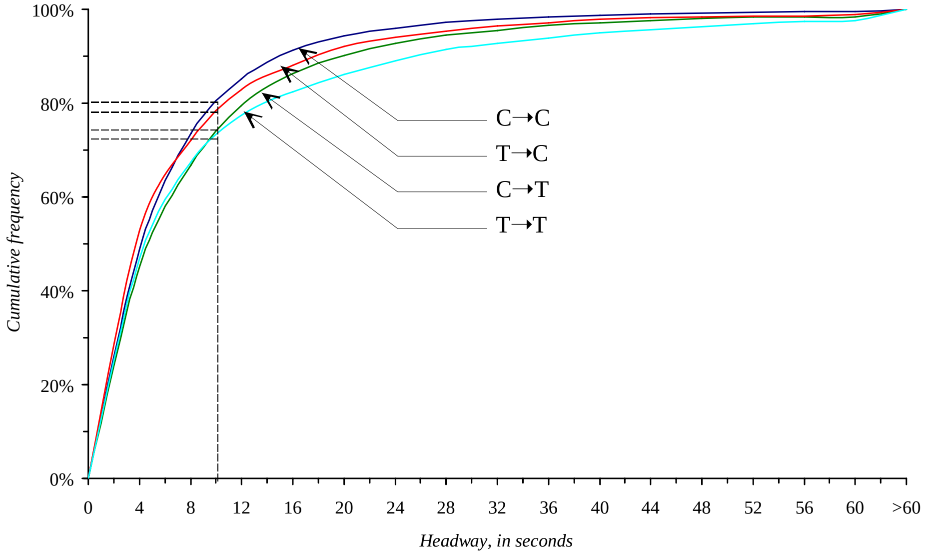

FIGURE 3 3: Cumulative distribution of headways in the middle lane at milepost 374

The data in Figure 3.3 show that "car following car" headways in the middle lane are generally larger than for all other headway categories while "truck following truck" headways are generally the lowest. Figure 3.4 depicts the distribution that is similar to that of Figure 3.3 with an exception that the lowest headway category on Figure 3.4 is "car following truck". If it is assumed that truck drivers would accept gaps of 10 seconds or more in the middle lane before initiating a passing maneuver, both Figures 3.3 and 3.4 show that truck drivers would have the opportunity to enter the middle lane on the average 25 percent of the time. Cumulative distribution graphs for all headways regardless the type of the lead or following vehicle showed that trucks would be able to move into the middle lane approximately 25 percent of the time thus confirming the results in Figures 3.3 and 3.4. Due to heavy volume of trucks during the truck peak hour, it follows that there would be even more passing opportunities in other hours.

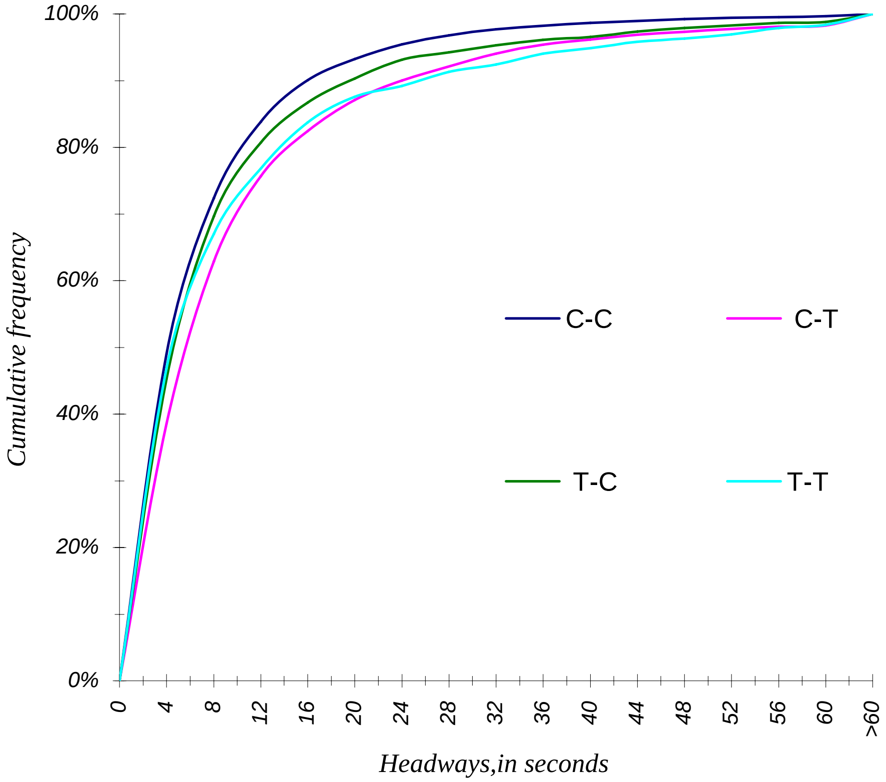

FIGURE 3.4: Cumulative distribution of headways in the middle lane at Milepost 428

The same headway analysis was done for each lane of travel to find out whether vehicles had enough opportunities to make lane change maneuvers from the middle lane to the outside lane or from the middle lane to the inside lane. Most of the time vehicles change lane to the outside lane at the exits and in most cases cars change lane to the inside lane to avoid trucks since, per lane restriction in this corridor, trucks are not supposed to be in the inside (or inside) lane. The headway distributions on all lanes were the same as those shown on Figures 3.3 and 3.4.

A statistical analysis was conducted to determine if there were significant differences between these headway types on different lanes—restricted and unrestricted. The statistical analysis was conducted using Fisher's Least Significant Difference procedure which provides confidence intervals for pairwise differences. The method is well suited for data that have dissimilar sample size. The results of the Fisher LSD statistical tests are at mileposts 374 and 428 are shown in Table 3.1 and 3.2 respectively. The cells that are underlined and bolded indicate there was a significant difference between the pair at 95 percent confidence interval.

TABLE 3.1: Pairwise Comparison of Average Hourly Headways at Milepost 374

		Inside Lane	**Middle Lane**				**Outside Lane**		
		C→C	**C→C**	**C→T**	**T→C**	**T→T**	**C→C**	**C→T**	**T→C**
Middle Lane	**C→C**	23.0 to –76.2							
	C→T	**22.2 to 75.4**	-25.8 to 27.4						
	T→C	**23.7 to 76.9**	**-27.3 to –25.9**	-28.2 to 25.0					
	T→T	22.7 to –75.9	-26.3 to 26.9	-26.1 to 27.1	-27.7 to 25.5				
Outside Lane	**C→C**	**23.6 to 76.8**	-26.0 to 27.2	-25.2 to 28.0	-26.8 to 26.4	-25.2 to 28.0			
	C→T	**24.9 to 77.9**	-26.9 to 30	-27.2 to 26.0	-27.8 to 24.6	-26.7 to 28.6	-26.6 to 26.6		
	T→C	**24.8 to 78.0**	-24.8 to 28.4	-23.9 to 29.3	-25.5 to 27.7	-24.5 to 28.7	-27.9 to 25.3	-29.4 to 30.3	
	T→T	**24.3 to 77.5**	-25.3 to 27.9	-24.4 to 28.8	-26.0 to 27.2	-24.4 to 28.8	-27.4 to 25.8	-25.8 to 27.4	-27.1 to 26.1

Closer examination of Table 3.1 and Table 3.2 shows a recurring theme which is that the average headways in the outside lane are significantly lower than in the inside lane for all four headway types. However, when the middle lane headways are compared to those in the inside lane, the data in Table 3.1 and Table 3.2 show that there is no significant difference between "car following car" headways on these two lanes adjacent lanes. In addition, the "car following car" headways on the inside lane are not significantly different from “truck following truck” in the middle lane. This suggests that trucks in the middle lane travel at significantly higher speed and close to each other just as cars travel in the inside lane.

TABLE 3.2: Pairwise Comparison of Average Hourly Headways at Milepost 428

		Middle lane				**Inside lane**			**Outside lane**		
		T→C	**C→T**	**C→C**	**T→T**	**T→C**	**C→T**	**C→C**	**T→C**	**C→T**	**C→C**
Middle lane	**C→T**	-19.86 to 15.94									
	C→C	-17.80 to 18.00	-15.84 to 19.96								
	T→T	-16.92 to 18.87	-14.96 to 20.83	-17.02 to 18.77							
Inside lane	**T→C**	-27.86 to 8.71	-25.90 to 10.67	-27.96 to 8.61	-28.83 to 7.73						
	C→T	**-64.45 to -27.88**	**-62.49 to -25.93**	**-64.55 to -27.98**	**-65.42 to -28.86**	**-55.25 to -17.93**					
	C→C	**-67.92 to -32.13**	**-65.96 to -30.17**	-48.02 to 32.23	-38.89 to 33.10	**-58.73 to -22.17**	-22.14 to 14.43				
Outside lane	**T→C**	-18.84 to 16.96	-16.88 to 18.91	-18.94 to 16.86	-19.18 to 15.98	**-9.65 to -26.92**	**26.94 to 63.51**	**31.18 to 66.98**			
	C→T	-18.72 to 17.07	-16.77 to 19.03	-18.82 to 16.97	-19.70 to 16.10	**-9.53 to -27.03**	27.06 to **63.62**	**31.30 to 67.09**	-17.78 to 18.01		
	C→C	-17.06 to 18.73	-15.11 to 20.69	-17.16 to 18.63	-18.04 to 17.76	**-7.87 to -28.69**	28.72 to **65.28**	**32.96 to 68.75**	-16.12 to 19.67	-16.24 to 19.56	
	T→T	-18.56 to 17.23	-16.6 to 19.19	-18.66 to 17.13	-19.54 to 16.26	**-9.37 to -27.19**	**27.22 to 63.78**	**31.46 to 67.26**	-17.62 to 18.17	-17.73 to 18.06	-19.39 to 16.40

Examination of the pairwise comparisons in Table 3.1 and Table 3.2 shows that there are no significant differences on the middle and outside lanes for “car following car” and “car following truck” headways. This implies that trucks do not impede cars in these lanes as they they are traveling as fast as cars since the data shows that there is no difference in headways whether a car is following another car or a car is following a truck. There are other few significant differences that can be deduced from Tables 3.1 and 3.2 but do not have much relevance in the scheme of this analysis.

The relationship between speed and headway was also analyzed. The analysis was broken down into headway categories discussed above—that is, car following car, car following truck, truck following car, and truck following truck. For each headway category, the speeds of the lead vehicles were averaged and the standard deviations were calculated. The results are shown in Appendix E. Closer examination of the results in Appendix E shows that there is no particular trend since some both long and short headways were prevalent at low and high speeds. However, headways in the inside lane showed more variability than headways on the other lanes probably because of less volume on this lane compared to the other lanes.

3.3 Analysis of Passing Opportunities for Trucks

Further analysis was conducted to determine the distribution of gaps of sufficient size to enable trucks to pass slow moving vehicles. Since trucks are not allowed to use the inside lane, the analysis was aimed at available passing opportunities in the middle lane. The 24-hr volume data for the middle lane were analyzed to determine the peak hour traffic. It was indicated earlier in Figure 3.1 that truck traffic peaks at different times from the passenger car traffic. For the purposes of this analysis, the peak hour was chosen as the hour with most traffic—that is, trucks and passenger cars combined. Table 3.3 shows the cumulative distribution of headways in the middle lane for northbound direction.

TABLE 3.3: Probability of assumed minimum headway required by a truck to pass

Minimum headway, *t*, a truck can use to pass	**Probability of headway, *h*, being equal or greater than specified value of *t*** $P(h \geq t)$	$1 - P(h \geq t)$
4	0.53	0.47
6	0.39	0.61
8	0.33	0.67
10	0.27	0.73
12	0.21	0.79
14	0.18	0.82
16	0.15	0.85
18	0.12	0.88
20	0.10	0.90

The geometric probability distribution was used to find the number of vehicles, *n*, that will pass in the middle lane before a truck gets a passing opportunity—that is a gap with a value equal to or greater than *t* as defined in Table 3.3. This is a discrete probability distribution that describes the probability that a Bernoulli experiment—a stochastic process consisting of finite or infinite sequence of independent random variables with each variable having a possibility of either failure or success—will have its first success on the *n*th trial. The mathematical expression of the distribution is

$$P(X = n) = p.(1 - p)^{n-1} \qquad (1)$$

where $P(X = n)$ denotes the probability of n vehicles passing before a truck gets a passing opportunity, p is the probability of the headway being greater or equal to the headway required for truck to pass (See Table 3.3), n is the number of vehicles that will pass before a truck gets a passing opportunity, and t is the assumed time headway required by a truck driver to make the passing maneuver. The cumulative probability for different values of t is shown in Table 3.4 and is also plotted in Figure 3.5. The cumulative probability is the sum of , and plotted against number of vehicles n for different assumed values of time headway t as shown on figure 3.5. which is a sum of individual $P(X = n)$.

TABLE 3.4: Cumulative probabilities for different *t* values

	Cumulative probability (sum of p(X=n)) for each t value								
N	***t*=4**	***t*=6**	***t*=8**	***t*=10**	***t*=12**	***t*=14**	***t*=16**	***T*=18**	***t*=20**
1	0.5300	0.3900	0.3300	0.2700	0.2100	0.1800	0.1500	0.1200	0.1000
2	0.7791	0.6279	0.5511	0.4671	0.3759	0.3276	0.2775	0.2256	0.1900
3	0.8962	0.7730	0.6992	0.6110	0.5070	0.4486	0.3859	0.3185	0.2710
4	0.9512	0.8615	0.7985	0.7160	0.6105	0.5479	0.4780	0.4003	0.3439
5	0.9771	0.9155	0.8650	0.7927	0.6923	0.6293	0.5563	0.4723	0.4095
6	0.9892	0.9485	0.9095	0.8487	0.7569	0.6960	0.6229	0.5356	0.4686
7	0.9949	0.9686	0.9394	0.8895	0.8080	0.7507	0.6794	0.5913	0.5217
8	0.9976	0.9808	0.9594	0.9194	0.8483	0.7956	0.7275	0.6404	0.5695
9	0.9989	0.9883	0.9728	0.9411	0.8801	0.8324	0.7684	0.6835	0.6126
10	0.9995	0.9929	0.9818	0.9570	0.9053	0.8626	0.8031	0.7215	0.6513
11	0.9998	0.9956	0.9878	0.9686	0.9252	0.8873	0.8327	0.7549	0.6862
12	0.9999	0.9973	0.9918	0.9771	0.9409	0.9076	0.8578	0.7843	0.7176
13	0.9999	0.9984	0.9945	0.9833	0.9533	0.9242	0.8791	0.8102	0.7458
14	1.0000	0.9990	0.9963	0.9878	0.9631	0.9379	0.8972	0.8330	0.7712
15	1.0000	0.9994	0.9975	0.9911	0.9709	0.9490	0.9126	0.8530	0.7941

The results in Table 3.4 and Figure 3.5 shows that if the accepted gap is assumed to be 10 seconds then there is 92 percent probability that the maximum number of vehicles that will pass before a truck gets a passing opportunity is eight (*n*=8). This means that if the accepted gap for trucks to make a passing maneuver is assumed to be 10 sec, then the probability that any combination of vehicles (trucks or passenger cars) less than or equal to 8 but not more than 8 may pass before a truck gets a passing opportunity is 0.92. Figure 3.5 can be used to find the probability and *n* vehicles that will pass before truck gets a passing opportunity in the middle lane during the congested period of the day using any reasonable assumed value of acceptable gap, *t*. Since peak hours for trucks and passenger cars are not exactly the same as was shown in Figure 3.1, the same analysis was conducted for headway distributions when the trucks volume was slightly higher than other periods of the day and was also done for data from milepost 428 but results very similar to those displayed in Table 3.4 and Figure 3.5.

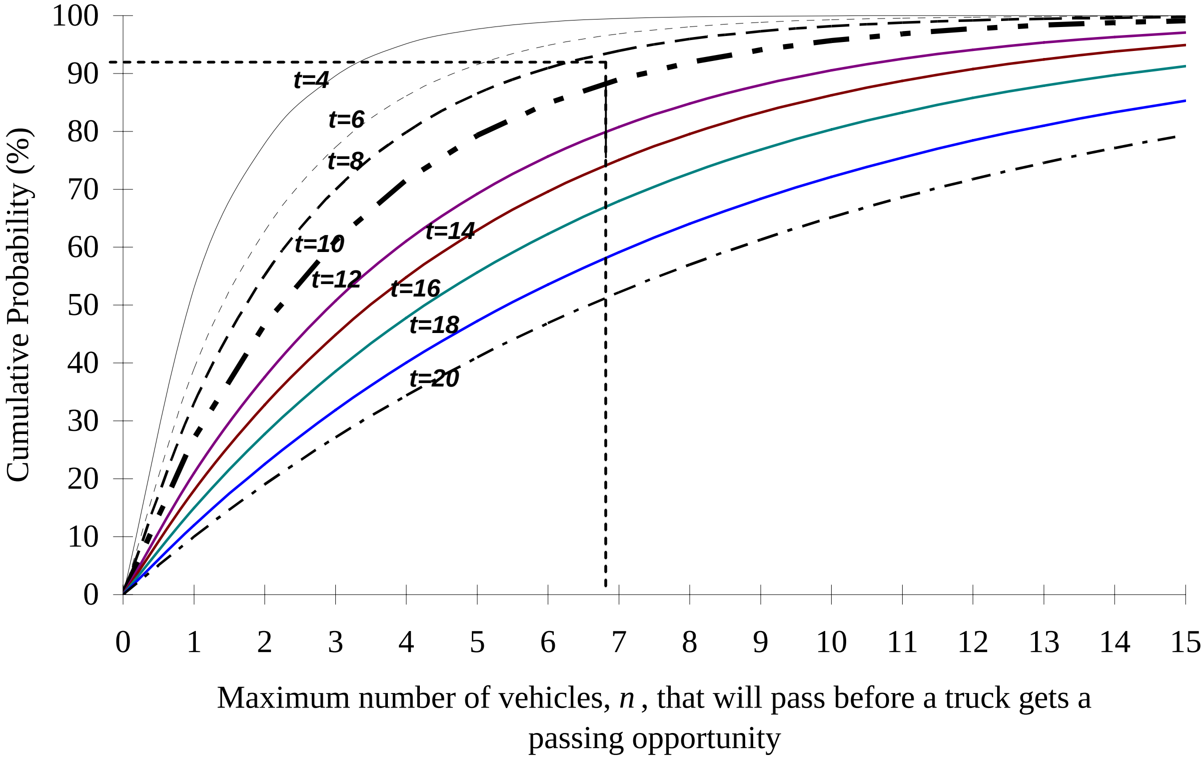

FIGURE 3.5: Cumulative Distribution of $P(X = n)$ in the middle during the overall peak hour

3.4 Speed Analysis

The operating speed of an individual vehicle is an important measure on how a facility serves the traveling public. Long distance travelers on limited access facilities tend to maximize their speeds—often within the limits of speed regulation—in order to minimize their travel time.

Thus, it was important to analyze how the regulation of restricting trucks from using the inside lane on this stretch of I-75 affected individual vehicle speeds for both passenger cars and trucks.

3.4.1 Speed Characteristics at Milepost 374

A full day of individual vehicle records were downloaded from a telemetered traffic monitoring site at milepost 374 on Tuesday, April 30, 2002. The data were time-stamped—i.e., showed the time the vehicle was recorded. The individual vehicle speed, vehicle classification, and the lane of passage were also recorded. There were a total of 49,126 vehicles that were recorded in the 24-hr period. Table 3.5 shows the average vehicle speeds categorized by time-of-day, vehicle type, and by lane. The time-of-day data are shown in blocks of 3 hours for brevity since the hourly data did not show much variation from the 3-hr averages. The data are for northbound direction only since the southbound direction had trends similar to those shown in Table 3.5.

TABLE 3.5: Average Northbound Speed Characteristics at Milepost 374

Time-of-day	Inside Lane		Middle Lane		Outside Lane	
	Cars	**Trucks**	**Cars**	**Trucks**	**Cars**	**Trucks**
00:00 – 3:00	72.7	73.0*(n=4)*	73.4	70.6	66.7	66.1
03:01 – 06:00	73.5	73.8(*n=6)*	73.0	70.2	67.9	65.5
06:01 – 09:00	75.5	73.7(*n=11)*	74.3	70.5	69.4	65.8
09:01 – 12:00	75.1	73.9(*n=12)*	73.5	70.8	68.6	65.0
12:01 – 15:00	74.8	73.4(*n=19)*	73.2	69.9	68.0	64.8
15:01 – 18:00	75.5	73.2(*n=18)*	73.6	71.7	68.6	65.7
18:01 – 21:00	76.0	73.1(*n=18)*	74.4	72.3	69.3	66.2
21:01 – 00:00	74.6	72.0*(n=6)*	73.0	71.1	67.6	66.8
Daily Avg.	74.7	73.3(*n=13)*	73.6	70.9	68.3	65.7

In analyzing the data in Table 3.5, lets first consider speed differences in lanes that are not restricted from truck use—i.e., the middle and outside lanes. On the average, the difference between passenger car and truck speeds (passenger car speed minus truck speed) is 2.7 mph and 2.6 mph for middle and outside lanes, respectively. These differences were found not to be significant ($p=0.13$ for middle lane and $p=0.11$ for outside lane). The 85th percentile speeds for passenger cars were 79.2 mph and 76.3 mph for middle and outside lanes, respectively. For trucks, the 85th percentile speeds were 77.9 mph and 75.1 mph for middle and outside lanes, respectively. These values are significantly higher than the speed limit of 70 MPH posted throughout this section of I-75. The 10-mph pace for passenger cars and trucks in the middle lane are 69.5 to 79.5 mph and 68.5 to 78.5 mph, respectively. The percentages of vehicles within these ranges were 72.4 and 68.0 for passenger cars and trucks, respectively. For the outside lane, the 10-mph pace are 67.2 to 77.2 mph and 64.5 to 74.5 mph for passenger cars and trucks, respectively. The percentages of vehicles within these ranges were 67.3 and 65.0 for passenger cars and trucks, respectively.

The inside lane, which trucks are restricted from using is analyzed next. A small number of heavy vehicles were recorded in this lane as shown in brackets in column 3 of Table 3.5. The majority of the heavy vehicles recorded were trucks violating the lane restriction but some were buses and trucks with less than six wheels but with vehicle dimensions similar to the types that are restricted from using this lane. Comparison of the average passenger car speeds on inside and middle lane shows that overall the passenger cars in the inside lane travel faster by 1.1 mph. This difference, however, was found not to be significant *(p=0.22).* The 10-mph pace for passenger cars in this lane was 71.3 to 81.3 mph while for trucks it was 68.2 mph to 78.2mph. The percentages of vehicles within these ranges were 80 and 76 for passenger cars and trucks, respectively.

3.4.2 Speed Characteristics at Milepost 428

Data were downloaded from a telemetered traffic monitoring site at Milepost 428 on Thursday, July 11, 2002. There were a total of 22,165 and 24,605 vehicles that were recorded in the 24-hr period for northbound and southbound directions, respectively. Tables 3.6 shows the results for the southbound direction.

TABLE 3.6: Average Southbound Speed Characteristics at Milepost 428

Time-of-day	**Inside Lane**		**Middle Lane**		**Outside Lane**	
	Cars	**Trucks**	**Cars**	**Trucks**	**Cars**	**Trucks**
00:00 – 3:00	80.4	85.0*(n=2)*	74.1	72.5	71.2	69.3
03:01 – 06:00	81.0	89.0(*n=1)*	75.3	73.0	70.4	67.4
06:01 – 09:00	80.7	80.0(*n=10)*	75.7	74.3	70.8	67.1
09:01 – 12:00	80.8	80.3(*n=15)*	75.6	73.8	71.2	68.2
12:01 – 15:00	81.2	82.3(*n=18)*	75.9	73.7	71.0	68.3
15:01 – 18:00	81.4	79.9(*n=12)*	76.2	73.6	71.5	68.0
18:01 – 21:00	80.7	81.7(*n=14)*	76.1	72.9	70.8	67.4
21:01 – 00:00	80.1	77.8*(n=9)*	74.7	72.1	70.7	67.9
Daily Avg.	80.8	82.0(*n=11)*	75.5	73.2	71.0	68.0

The results in Table 3.6 shows that the difference between passenger car and truck speeds (passenger car speed minus truck speed) is 2.3 mph and 3.0 mph for middle and outside lanes in the southbound direction, respectively. However, these differences were not statistically significant (*p=0.12* for middle lane and *p=0.17* for outside lane in northbound). The 85th percentile speeds for passenger cars in southbound were 75.9 mph for middle lane and 71.4 mph for outside lane. The 85th percentile speeds for trucks were 72.7 mph and 70.3 mph for middle and outside lanes, respectively. The 10-mph pace for the outside lane were 68.4 to 78.4 mph and 67.2 to 77.2 mph for passenger cars and trucks, respectively. The percentages of vehicles within these ranges were 67.6 and 66.3 for passenger cars and trucks, respectively. In the middle lane, the 10-mph pace for passenger cars and trucks are 71.4 to 81.4mph and 69.9 to 79.9 mph, respectively. Comparison of the average passenger car speeds on inside and middle lane shows that overall the passenger cars in the inside lane were traveling faster by 5.3 mph. This difference, however, was found not to be significant *(p=0.15).*

A careful evaluation of speeds on this corridor reveals that the majority of passenger cars and trucks travel at very high speeds close to and exceeding the speed limit of 70 mph as envisaged by the percentage of vehicles in the pace ranges shown above. The high operating speed of trucks in both day and night time clearly shows that the lane restriction does not negatively impact speeds of trucks in this stretch of I-75. However, the speed data that were analyzed and displayed in tables above are point or time mean speeds that one can argue that they can not be used to calculate the travel time of passenger cars and trucks across the study corridor. To determine the travel times across the corridor and other operational measures such as the number of lane changes with or without lane restrictions, a simulation analysis was conducted, the results of which are reported in the next section.

3.5 Simulation Analysis of the Corridor

The difference between operating characteristics of passenger cars and trucks was analyzed using CORSIM—which stands for CORridor SIMulation—software. CORSIM is a microscopic, time-stepping, stochastic simulation model capable of simulating corridors containing freeways and surface streets. The CORSIM model was reviewed to determine its capability and limitations in simulating the I-75 corridor. Of importance to the simulation study was the theory used by CORSIM to generate vehicles in the corridor, to space vehicles, and to initiate a lane change. It was also important to understand how truck lane restriction is handled in CORSIM.

CORSIM typically generates vehicles from entry links and source links nonstochastically (at uniform rate) or the user can specify a random number seed to generate stochastic vehicle entry headways using either normal or Erlang distribution (Halati *et al.,* 1997). CORSIM randomly assigns the generated vehicle to a lane as long as the minimum headway requirement is not violated. The FRESIM component of CORSIM uses the PITT car-following model, which is founded on a combination of the Northwestern car-following, and the UTCS-1 collision avoidance procedures (Halati *et al.,* 1997). The mathematical expression of the model is

$$h_{n+1} = L + 10 + k\dot{x}_{n+1} + bk(\dot{x}_n - \dot{x}_{n+1})^2 \qquad (2)$$

where h_{n+1} denotes space headway, $\dot{x}_{n+1}$ is the speed of the following vehicle at time *t*, $\dot{x}_n$ is the speed of the lead vehicle at time *t*, *L* is the length of the leading vehicle, *b* is constant, and *k* denotes driver sensitivity. The time headway between vehicles is directly proportional to the driver sensitivity factor, *k*, and therefore the higher the value of *k*, the lower the capacity of the roadway being simulated. The PITT car following model is of the form:

response=func(*sensitivity, stimuli*), the response being the acceleration of the following vehicle, the stimuli being the space headway, and sensitivity being the driver characteristics.

FRESIM models lane changing in three distinct categories: mandatory lane change, discretionary lane change, and anticipatory lane change. Of importance in this study, is the discretionary lane changing in which vehicles perform lane change to pass slow moving vehicles such as trucks. The FRESIM model assigns to each vehicle an intolerable speed, v_i—below which a driver is highly motivated to perform the lane change—which is given by

$$v_i = v_{ff}(50 + 2c)/100 \tag{3}$$

where v_{ff} is the desired free flow speed and c is the driver type factor which is randomly assigned a number between 1 to 10 with 10 representing the most aggressive driver and 1 representing the most timid driver (Halati *et al.*, 1997). It is noteworthy that CORSIM does not allow the user to change any default value and functional relationships used in the discretionary lane changing model.

The geometrics of the 54-mile corridor of I-75 were coded in CORSIM. The geometric data were extracted from as-built drawings and condition diagrams derived from field visits. Efforts were made to include all geometrics that are likely to affect safety and operations including grades, inside widths, deceleration and acceleration lanes, etc. The traffic data were input using field data that was representative of time of day being simulated. The times of day of interest were daytime and nighttime defined by average volumes during those times. The entrance and exit volumes as well as the percentage of trucks on each lane, exit, or entrance ramps were coded in CORSIM for each scenario.

Ten scenarios representing a wide range of operating characteristics in the corridor were simulated. In each scenario, different driver type and random number seeds were used. Several simulation runs were performed for each scenario. For each scenario, data on travel time and delay were recorded and averaged. Similarly, data for the number of lane changes were recorded. In order to increase the realism of simulation, the CORSIM model was validated using field data which represent the lane restriction scenario as it exists in the field. The calibration was conducted by inputing traffic and geometric conditions that are representative of the observed field values and determining the conformity of simulation outputs of relevant measures of effectiveness to the observed field values.

3.5.1 Travel Time and Delay Analysis

Table 3.7 shows the comparison of average travel time and average delay in the corridor for a situation in which trucks are restricted from using the inside lane and a situation in which all vehicles are allowed to use all lanes. The averages are for the ten scenarios described above. The numbers in parentheses are the standard deviations.

TABLE 3.7: Simulation results of travel time and delay in the corridor

	Restricted	**Unrestricted**		
	$\overline{X}$ **(*s*)**	$\overline{X}$ **(*s*)**	***t* statistic**	***p-value***
Daytime				
Travel time, in *min/veh*	49.07 (0.24)	49.05 (0.23)	-0.845	0.4199
Delay, in *sec/veh*	397 (84.9)	399 (89.7)	-1.347	0.211
Nighttime				
Travel time, in *min/veh*	48.90 (0.07)	48.50 (0.08)	-0.332	0.7477
Delay, in *sec/veh*	224 (73.4)	214 (71.6)	-0.165	0.8722

Table 3.7 shows that there is no significant difference in travel time and delay on the freeway for restricted and unrestricted conditions for both daytime and nighttime. The daytime was defined as 7 a.m. to 7 p.m. while the nighttime was defined as 7 p.m. to 7 a.m. The high *p*-values in Table 3.7 suggest that the travel time and delay are not significantly affected by truck restriction on the inside lane regardless of whether it is daytime or nighttime.

3.5.2 Lane Change Analysis

Table 3.8 shows the average number of lane changes for restricted and unrestricted conditions for both daytime and nighttime. The results in Table 3.8 show that there were consistently fewer lane changes at night compared to the daytime whether or not the inside lane was restricted. This is due to the fact that the volume level simulated to represent nighttime conditions was lower than the daytime volume; consequently, there is less platooning of vehicles moving at speeds slower than $v_i = v_{ff}(50+2c)/100$ which would trigger desire to change lanes.

TABLE 3.8: Simulation results for number of lane changes on the corridor

	Restricted	**Unrestricted**		
	$\overline{X}$ **(*s*)**	$\overline{X}$ **(*s*)**	***t* statistic**	***p*-value**
Daytime				
Number of lane changes	12,693 (3,957)	13,484 (4,382)	4.35	0.0019
Nighttime				
Number of lane changes	9,301 (2,299)	10,275 (2,751)	0.946	0.03691

However, the data show that the average number of lane changes increased significantly in both day and night when trucks were allowed to use all three lanes. This result might have safety implications. The increase in the number of lane changes suggests that impatient drivers are performing an increasing number of discretionary lane changing to maximize their speeds. This would inevitably increase the likelihood of conflicts between vehicles in the traffic stream leading to the potential for more crashes in this corridor. The next chapter discusses safety analysis in the corridor.

CHAPTER 4--SAFETY ANALYSIS

4.1 Introduction

The impact of truck lane restriction is measurable in terms of traffic operating characteristics and the level of safety prevailing in the corridor. Generally the relationship between traffic operations and safety—as measured by crash occurrences—is not clear cut. There are cases in which roadways were operating at worst level of services—as measured by volume and speed—and yet crash occurrences were minimal. On the other hand, there were roadways with better operating characteristics but had high incidences of crash occurrences. Thus, even though analysis in Chapter 3 revealed that the corridor was operating at acceptable level of service despite the truck restriction, it is important to analyze crash experience in this corridor.

Like passenger cars, large trucks also get involved in crashes. According to crash statistics published by the National Highway Traffic Safety Administration (NHTSA), 5,104 people were killed died in crashes involving large trucks. Fourteen percent of people who died in these crashes were truck occupants, 74 percent were passenger car occupants, and 10 percent were either pedestrians, bicyclists, or motorcyclists. Ninety-eight percent of people killed in two-vehicle crashes involving a passenger car and a large truck were occupants of the passenger vehicles. Of the vehicles involved in the fatal crashes, 84 percent were large trucks and 62 percent of passenger cars. Since 1979, when truck crash deaths were at an all-time high, truck crashes have declined by 22 percent overall (50 percent among truck occupants and 10 percent among passenger vehicle occupants). Fifty-seven percent of deaths in large truck crashes occurred on major roads, 28 percent occurred on freeways, 9 percent occurred on minor roads, and 6 percent occurred on unknown road types. More large truck crash deaths occur during the day than at night and most occur on weekdays (NHTSA, 2002).

The thrust of this chapter is to review crashes that occurred in the study corridor. The review involves several attributes of the crashes including crash types, severity of crashes, contributing causes, most likely driver's violation behaviors, and the type of the vehicle involved. Also analyzed, is time of the day in which the crash occurred. Hard copies of police reports for each crash that occurred in the corridor from January 1, 1999 to December 31, 2000 were acquired from the Florida Department of Transportation, State Safety Office. The data were summarized using Highway Safety Analysis (HSA) software.

4.2 Overall View of Crash Occurrence

A total of 426 crashes were reported for the two-year period—from January 1, 1999 to December 31, 2000. A total of 715 vehicles were involved in these crashes in which 105 vehicles (14.7 percent) were trucks and 610 vehicles (85.3 percent) were passenger cars. Comparing the level of trucks' involvement to the data displayed in Chapter 3, it seems that trucks were not overrepresented in these crashes since only 14.7 percent of the vehicles that were involved in crashes were trucks, while close to 20 percent of vehicles traveling in this corridor were trucks. Although the operational data were downloaded from the sites in 2002 while the crash data were for previous years, the review of traffic data over the last five years showed that the proportion of trucks in this corridor from year to year have not changed significantly.

The data show that passenger cars were overrepresented in crashes occurring in this corridor. The operational analysis showed 80% passenger cars in the traffic stream while the crash data showed that passenger cars involvement was 85.3%. Although passenger cars were overrepresented in the overall crash statistics, the severity of the crashes was low since since most of the crashes were property damage only (PDO) and injury crashes. Figure 4.1 depicts the number of crashes for two years by severity. Mostly crashes on Interstate 75 are rear end, ran off roadway, and sideswipe type of crashes.

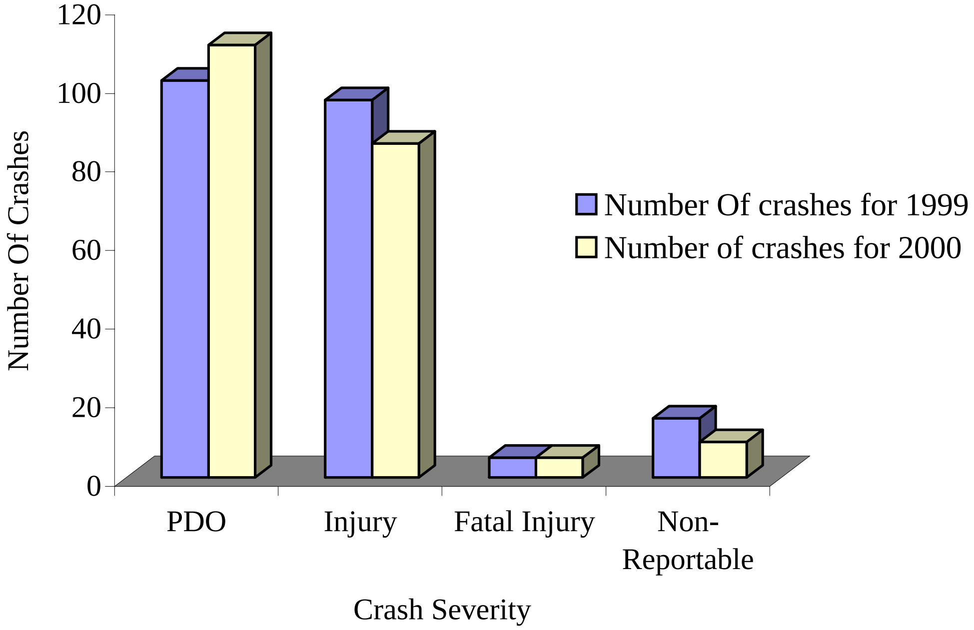

FIGURE 4.1: Severity of the Crashes

The analysis of police reports on these crashes showed that the major contributing causes for the crashes were overspeeding and improper lane change in which a driver initiated an improper passing maneuver. The crash rates for 1999 and 2000 were calculated as 0.31 crashes per million vehicle miles and 0.30 crashes per million vehicle miles respectively. The average crash rate for the two years was 0.31 crashes per million vehicle miles of travel. The overall crash results in terms of severity, type of crashes, vehicle movement, vehicle speeds, contributing causes and time-of –the day are summarized in Appendix F.

4.3 Crash Analysis by Time of Occurrence

Figure 4.2 shows the percentage of crashes occurring at a particular time period of the day. The data in Figure 4.2 shows that more crashes occurred during daylight hours than at night hours. This can partly be explained by the fact that there were more traffic in the day than at night. In addition, the operational analysis reported in Chapter 3 showed that operating speeds were slightly higher during the daytime compared to the nighttime.

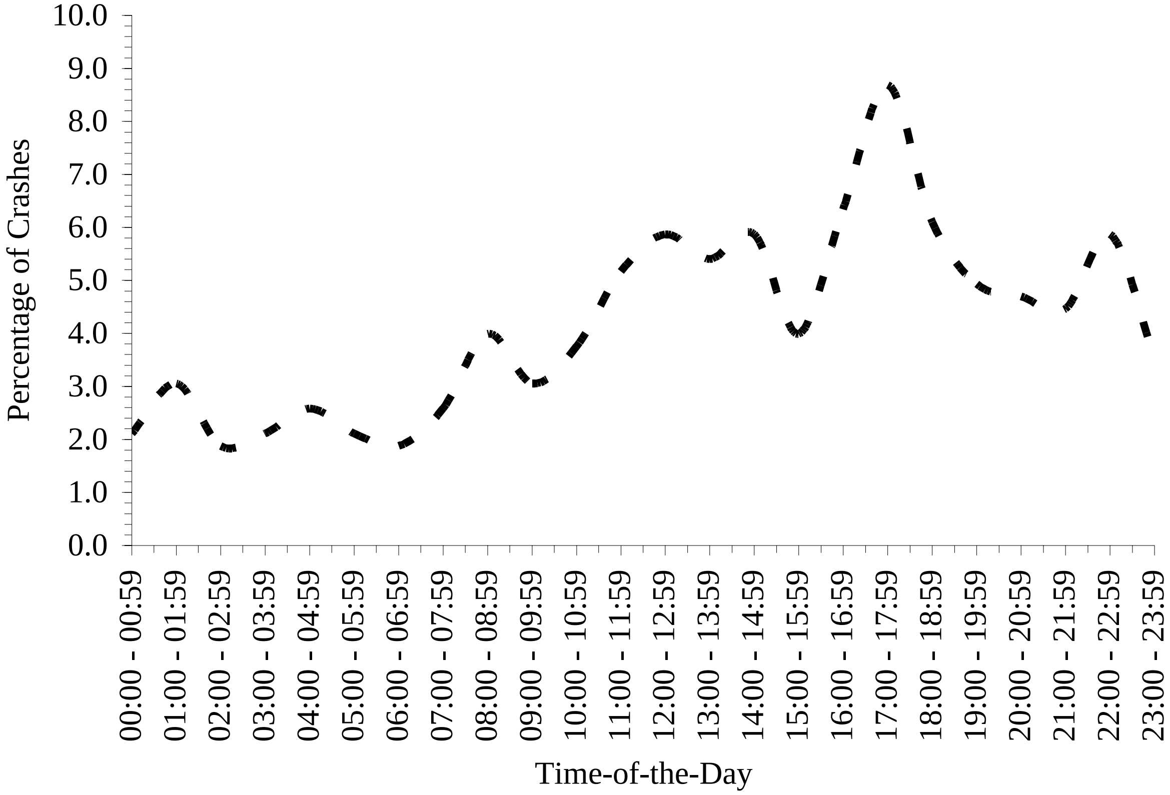

FIGURE 4.2: Time of Occurrence Analysis

4.4 Analysis of Trucks Involvement in Crashes

A total of 88 crashes (20.7 percent) were truck-related while the remaining 338 (79.3 percent) involved passenger cars only. Trucks were equally involved in daytime and nighttime crashes; however, in analyzing crashes where trucks were at fault it was found that a number of crashes caused by trucks is subtly higher during the day than nighttime. Crashes involving trucks by severity were 3 fatal crashes (3.4 percent), 18 injury crashes (20.5 percent) and 67 property damage only crashes (76.1 percent). According to the statistics compiled by the National Highway Traffic Safety Administration (NHTSA), the 1998 fatality rate per 100 million vehicle miles traveled for truck-related crashes was 2.1 while the national rate in the same year was 1.6 fatalities per 100 million vehicle miles traveled. The data further showed that the 1999 Florida fatality rate for truck-related crashes was 2.4 fatalities per 100 million vehicle miles of travel. The average fatality rate on the Interstate 75 corridor under study for the two-year analysis period was 1.5 fatalities per 100 million vehicle miles traveled.

4.5 Analysis of Crash Types and Contributing Causes

Table 4.1 summarizes crashes involving trucks only. The purpose of stratification of the data in Table 4.1 is to determine what types of crashes are trucks involved in, what were the contributing causes, and what was the vehicle action prior to the crash. Also shown in Table 1 is time of the day in which the crash occurred. Additional tables summarized different attributes of crash occurrence for trucks and for all vehicles are shown in Appendix G.

TABLE 4.1: Summary of Crash Statistics Involving Trucks Only

Crash type	**1999**	**2000**	**Total**	**Percent**
Rear-end	13	15	28	31.8
Sideswipe	17	12	29	33.0
Angle	8	1	9	10.2
Ran-off road	3	8	11	12.5
Collision with parked car	2		2	2.3
Collision with moveable object on road	7	1	8	9.1
Collision with pedestrian		1	1	1.1
Total	50	38	88	100
Vehicle Movement	**1999**	**2000**	**Total**	**Percent**
Straight ahead	53	52	105	64.4
Slowing/stopped	4	3	7	4.3
Backing				
Changing lanes	24	20	44	27.0
Properly Parked	3		3	1.8
Making a turn	2	2	4	2.5
Total	86	77	163	100
Lighting Condition	**1999**	**2000**	**Total**	**Percent**
Daylight	24	21	45	51.1
Dusk	1		1	1.1
Dawn	1		1	1.1
Dark (street light)	7	5	12	13.7
Dark (no street light)	17	12	29	33.0
Total	50	38	88	100

TABLE 4.1: Cont'd

Contributing Causes	1999	2000	Total	Percent
Reckless driving		2	2	2.2
Careless driving	12	11	23	25.2
Improper lane change	24	20	44	48.4
Exceeded stated speed limit	3		3	3.3
Exceeded safe speed limit	2	1	3	3.3
Speed too fast for conditions				
Improper passing	1		1	1.1
Obstructing traffic	2		2	2.2
Impaired (alcohol/drugs)	1	1	2	2.2
Following too closely	3		3	3.3
Other	6	2	8	8.8
Total	54	37	91	100

The results in Table 4.1 shows that the majority of the crashes involving trucks were rearend, sideswipe, and angle type collisions. The results further show that, prior to crash, the vehicles involved were either going straight ahead or were changing lanes. The data in Table 1 further reveals that the majority of the crashes involving trucks, slightly more than half, occurred during daylight hours. However, one third of the crashes occurred in darkness in areas without street lights. Night time conditions are generally characterized by poor visibility and inability of the driver to see further ahead. The contributing cause that was frequently cited in the police reports was improper lane changed accounting for close to half of all crashes involving trucks. In general, the overall data indicated that truck drivers were found at fault in 58 crashes (66 percent) of crashes in which a truck was involved.

CHAPTER 5--CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The growth of interstate and international commerce is continuing to fuel the increase of truck traffic on the United States Interstate freeway system. The difference in operating characteristics between large freight trucks and small passenger cars has raised concern for the safety and efficiency of highways, particularly on Interstate freeways where trucks form a large proportion of the traffic mix. To reduce the impact of trucks on highway safety and operations, various states have instituted measures restricting trucks from using certain lanes or routes during certain periods or all day long. Other types of restrictions include limiting the maximum speeds of trucks and designating truck routes. However, it is inevitable that these truck restrictive measures can be questioned in terms of their effectiveness or their impact on truck speeds and travel times. Also, it is logical to question whether some truck restriction measures go too far—for instance, is it necessary to restrict trucks from using certain lanes all day instead of just part of the day when traffic congestion is at the highest level?

This research study was sponsored by the Florida Department of Transportation, Office of Traffic Operations and was aimed at determining the impact of restricting trucks from using the median lane of a 139-mile, six-lane section of Interstate 75 freeway in north Florida. The trucks are restricted from using the inside lane in both southbound and northbound directions throughout the 24-hr period. Of particular interest in the study was the determination of the impact of the regulation on truck operating speeds and travel time. Both field data and simulation analysis were used to quantify the impact of the lane restriction on trucks and to predict the likely performance characteristics of passenger cars and trucks should the regulation be modified to restrict trucks only during the daytime or not to restrict at all.

The analysis of field data showed that the current 24-hr inside lane restriction policy does not have significant negative effects on trucks speeds. The 85th percentile speed of both passenger cars and trucks in the middle and outside lanes were in excess of 75 mph, which is 5 mph above the posted speed limit of 70 mph. Further simulation analysis to determine the travel time across a 54-mile sampled corridor showed that there was no significant difference between the travel times for all vehicles whether all lanes were opened to trucks or the inside lane was closed to trucks. This result suggests that with the current traffic flow levels and mix, there is not much to be gained for trucks or passenger cars if the policy is rescinded. However, the volume analysis and simulation results showed that there could be much to lose. The simulation analysis of lane changes showed that the number of lanes changes would significantly increase if the inside lane were to be opened to trucks. Frequent lane changes are a good predictor of the potential for increase in vehicular conflicts that could lead to crashes.

The analysis of crashes that occurred in this corridor for a two-year period from January 1, 1999 to December 31, 2000 revealed that improper lane change was the most frequent cited contributing cause for crashes occurring in this corridor. In crashes involving trucks only, improper lane change was cited 48% of the time. For all crashes that occurred in the corridor—that is, crashes involving trucks and passenger cars—improper lane change was cited 28 percent of the time. When this crash analysis result is viewed in context with the simulation results, it is prudent to conclude that rescinding the truck restriction policy in this corridor would have negative impact on safety as lane changing maneuvers are likely to increase with the attendant consequence of worsening crash experience in the corridor.

5.2 Limitations of the Study

The study reported herein depicted a comprehensive view of traffic operating characteristics and safety prevailing on the six-lane section of the Interstate 75 corridor in North Florida where inside lane truck restriction regulation is in force. The field and simulation results revealed the benefits of the truck restriction policy, the results of which were supported by the two-year crash data for the corridor. However, the results of this study are not necessarily transferable to other Interstate freeways in Florida for the following reasons. First, the Interstate 75 corridor that was studied is relatively uncongested with traffic operating at level of service B or better. Other Interstate freeways in Florida, particularly the Interstate 4 corridor running east-west from Tampa to Daytona Beach, might be operating at levels of service worse than B thus reducing passing opportunities for both trucks and passenger cars. Secondly, the area studied was primarily rural in character and do not represent urban corridors with short-spaced interchanges necessitating increased lane changes close to the exit and entrance ramps. The study section was a 3-lane section (one direction) in which one lane was restricted. Other Interstate freeways in Florida have sections ranging from 2-lane sections (one direction) to 5 or even 6-lane sections (one direction). These sections also have different traffic mix and geometric characteristics that might produce operations quite different from those pertaining to the Interstate 75 corridor studied.

5.3 Recommendations for Further Research

The study reported herein has given a localized view of safety and operating characteristics on a limited corridor of the Florida Interstate freeway system. A more global view of the system is needed to better quantify the benefits of truck lane restrictions around the state. There are other corridors in the state freeway system in which trucks are restricted from using certain lanes. Thus, a comprehensive study on all sections with truck lane restrictions is needed. The design of the study could also involve control site in which operating characteristics on freeway sections with truck lane restriction are compared with those sections that do not have truck lane restriction. The study could be expanded to include determining the influence of other factors on operations such as interchange spacing, truck percentage, number of lanes, and other geometric variables.

Where crash data are available, the before-and-after evaluation of the safety characteristics should be conducted. The study can examine, say, five-year crash data prior to the implementation of the restriction and compare the results to the crash experience five years after the implementation. The study can also compare the existing crash experience of “truck restricted” freeways to those in which trucks are not restricted. A cross-sectional study would be appropriate for these purposes.

Although CORSIM and other simulation tools can be used in an expanded study, it is clear that the delay and travel times across a corridor can be determined in the field. Recent advances in Global Positioning Systems (GPS) and satellite imagery provide field data collection tools that could assist in gathering information related to percent time delay, space mean speeds, and level of service across the whole corridor.

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APPENDICES

TABLE A.1: Lane restriction practices in the United States (Mannering *et al.*, 1993; Wishart & Hoel, 1996).

STATE	**TYPE OF RESTRICTION**	**OBJECTIVE OF RESTRICTION**	**EFFECTIVENESS OF THE RESTRICTION**
CALIFORNIA	To right most lane(s) trucks with 3+axles 24 hour operation on facilities with minimum 2+ directional lanes Statewide		
FLORIDA	From leftmost lane(s) trucks with 3+ axles 7 am to 7 pm enforced site specific	Improve safety Improve operation Reduce stress and intimidation for motorists	No change in safety No change in operation Near perfect compliance rate Positive public reaction
KANSAS	To leftmost lane(s) All trucks 24 hour operation not enforced facility with 2+ directional lanes statewide and voluntary	Equalize pavement wear	Deemed not successful
COLORADO	To right most lane(s) Variable weight limits Site specific		
CONNECTICUT	To right most lane(s) 24 hour operation commercial trucks and buses facility with 2+ directional lanes Statewide		
MASSACHUSETTS	To rightmost lane(s) Trucks with 10,000+ lbs GVW 24 hour operation Site specific		
NEVADA	To leftmost lane(s) All trucks voluntary Site specific	Equalize pavement wear	No change in safety 60% compliance Design life extended by 5-10 years, overlays reduced 10-20 %
NORTH CAROLINA	To leftmost lane(s)		
MISSOURI	To rightmost lane(s) All trucks On all urban freeways With minimum 3+ Directional lanes Statewide		

TABLE A-1: Continued

STATE	TYPE OF RESTRICTION	OBJECTIVEOF RESTRICTION	EFFECTIVENESS OF THE RESTRICTION
OREGON	To rightmost lane(s) On all urban freeways With minimum 2+ Directional lanes Trucks with 8,000+ lbs GVW.		
NEW YORK	To rightmost lane(s) (to left if no outsides on right) all trucks or 10,000+ GVW depending on location site specific		
NEW JERSEY	To rightmost lane(s) On all urban freeways with Minimum 3+ directional lanes 10,000+ lbs GVW. Statewide		
OKLAHOMA	Statewide		
GEORGIA	To rightmost lane(s)		Resulted into less weaving And fewer maneuvers
MARYLAND	To rightmost lane(s) on grades All trucks Site specific	Improve operation Improve safety Legislation and public pressure	
ILLINOIS	To rightmost lane(s) On facilities with minimum 3+ directional lanes All trucks Site specific	Improve operation	No change in speed High compliance rate Shorter queue lengths
KENTUCKY	To rightmost lane(s) Trucks with 30,000 lbs GVW On facilities with minimum 3+ directional lanes Site specific		
LOUISIANA	To rightmost lane(s) All trucks Not enforced Site specific		
IDAHO	To leftmost lane(s) All trucks On facilities with minimum 2+ directional lanes Site specific	Equalize pavement wear	

TABLE A-1: Continued

STATE	**TYPE OF RESTRICTION**	**OBJECTIVEOF RESTRICTION**	**EFFECTIVENESS OF THE RESTRICTION**
INDIANA	To rightmost lane(s) All trucks On all urban freeways With minimum 2+ Directional lanes 24 hour operation Statewide		
WISCONSIN	To leftmost lane(s) Rural facility Site specific	Equalize pavement wear	Low compliance rate Speed decreased in left lane. No change in queue length.
VIRGINIA	To rightmost lane(s) On limited access facilities with minimum 2+ directional lanes Site specific	Improve safety Public's interest Concerned with operational disparity between Maryland and Virginia	No change in speed truck and vehicle accidents decreased slightly. Positive motorist support
TEXAS	To rightmost lane(s) o Not enforced	Improve operation Trucks in the left lane were exceeding speed limit by > 10 mph on the average	No change in time gaps No change in speed 62% compliance rate 60% motorists in favor 28% truck drivers in favor
PENNSYLVANIA	To rightmost lane(s) on grades		

TABLE A-2: Time-of-day restriction practice in the United States (Mannering *et al.*, 1993; Wishart & Hoel, 1996).

STATE	**TYPE OF RESTRICTION**	**OBJECTIVEOF RESTRICTION**
KANSAS	Oversize/overweight trucks Variable hours On all urban freeways Statewide	
COLORADO	Overweight/ oversize trucks Permitted only during daylight Hours On all urban freeways Statewide	Improve safety
ILLINOIS	Oversize/Overweight trucks Prohibited 9:30 am to 3: 00 pm Site specific	Improve operation
INDIANA	Oversize/overweight trucks On all urban freeways	
CALIFORNIA		
ARIZONA	Oversize/overweight trucks Permitted only during the daylight hours, Monday through Friday On all urban freeways Statewide	Improve safety
IOWA	Oversize/overweight trucks Permitted only during daylight hours, Monday through Friday On all urban freeways Statewide	Improve safety
MINNESOTA	Oversize/overweight trucks Permitted only during daylight hours, Monday through Friday On all urban freeways Statewide	Improve safety
OKLAHOMA	Variable weights Variable hours On all urban freeways	
LOUISIANA	Oversize/overweight trucks Variable hours On all urban freeways Statewide	
OREGON	Oversize/overweight trucks Prohibited peak periods On all urban freeways Statewide	Improve operation
MARYLAND	Variable weight/size limits Variable hours On all urban freeways Statewide	Noise abatement through residential areas
PENNSYLVANIA	In large cities	
NEVADA		
NEW JERSEY		

TABLE A-2: Continued

STATE	**TYPE OF RESTRICTION**	**OBJECTIVEOF RESTRICTION**
WASHINGTON	Oversize/overweight trucks Restricted peak periods Through cities (15,000 + pop), Saturday, Sunday and holidays Statewide	Improve operation
RHODE ISLAND	Variable weight/size limits Variable hours Site specific – residential areas	Noise abatement through residential areas.
UTAH	Oversize/overweight trucks Prohibited peak periods through cities (15,000 + pop), Saturday, Sunday and holidays Statewide	Improve operation

TABLE A.3: Speed restriction practices in the United States (Mannering *et al.*, 1993; Wishart & Hoel, 1996).

STATE	**POSTED SPEED FOR PASSENGER CARS**	**POSTED SPEED FOR TRUCKS**
ALABAMA	65	55
WASHINGTON	65	60
VIRGINIA	65	55
OREGON	65	55
TEXAS	65	60/55*
OHIO	65	55
MICHIGAN	65	55
COROLADO	65	55
ILLINOIS	65	55
MISSOURI	65	60
INDIANA	65	60
CALIFORNIA	65	55

- Day/Night

APPENDIX B

Hourly Traffic Volume Distributions

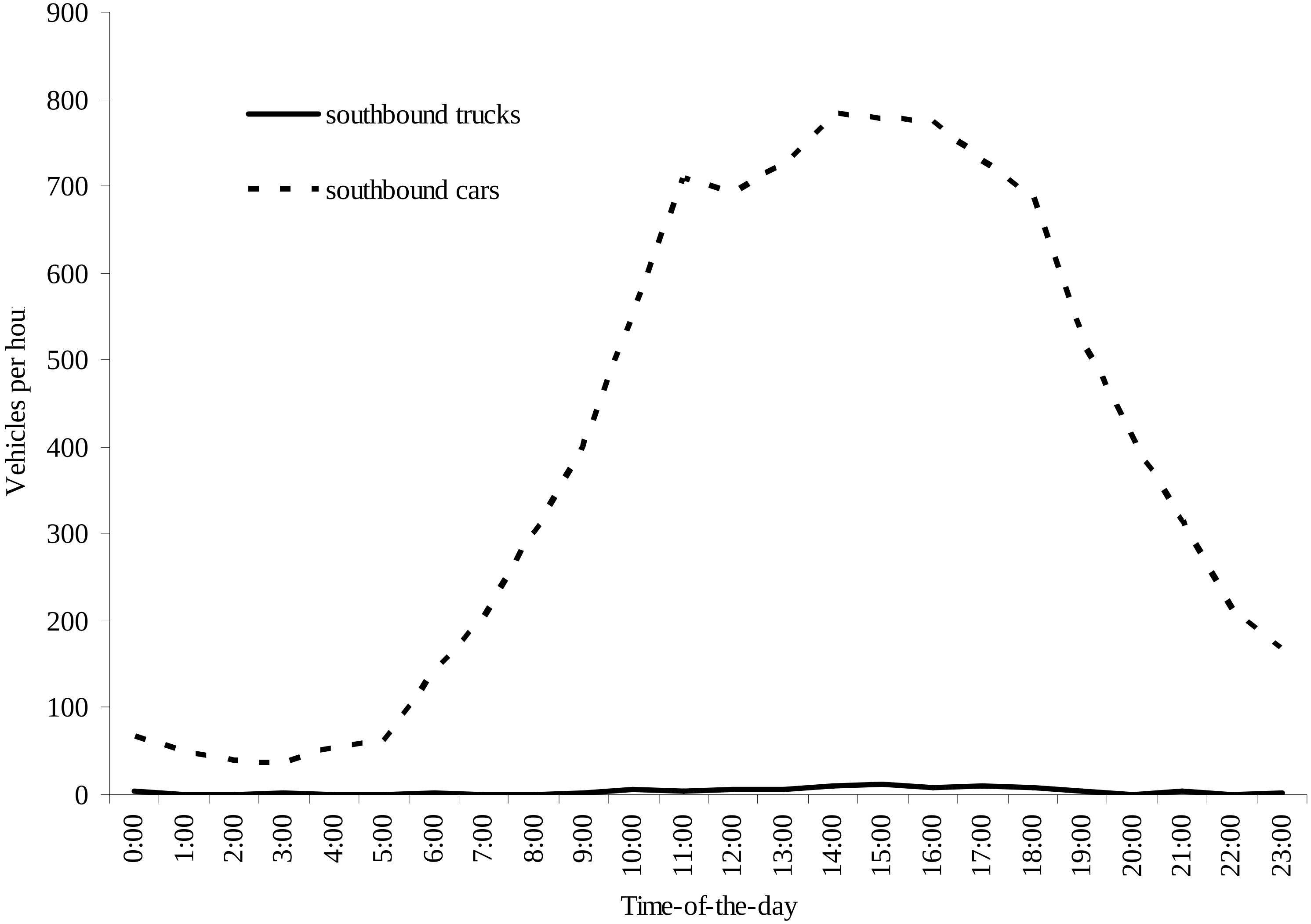


FIGURE B.1: Hourly Variation of Traffic on the Southbound Inside Lane at Milepost 374

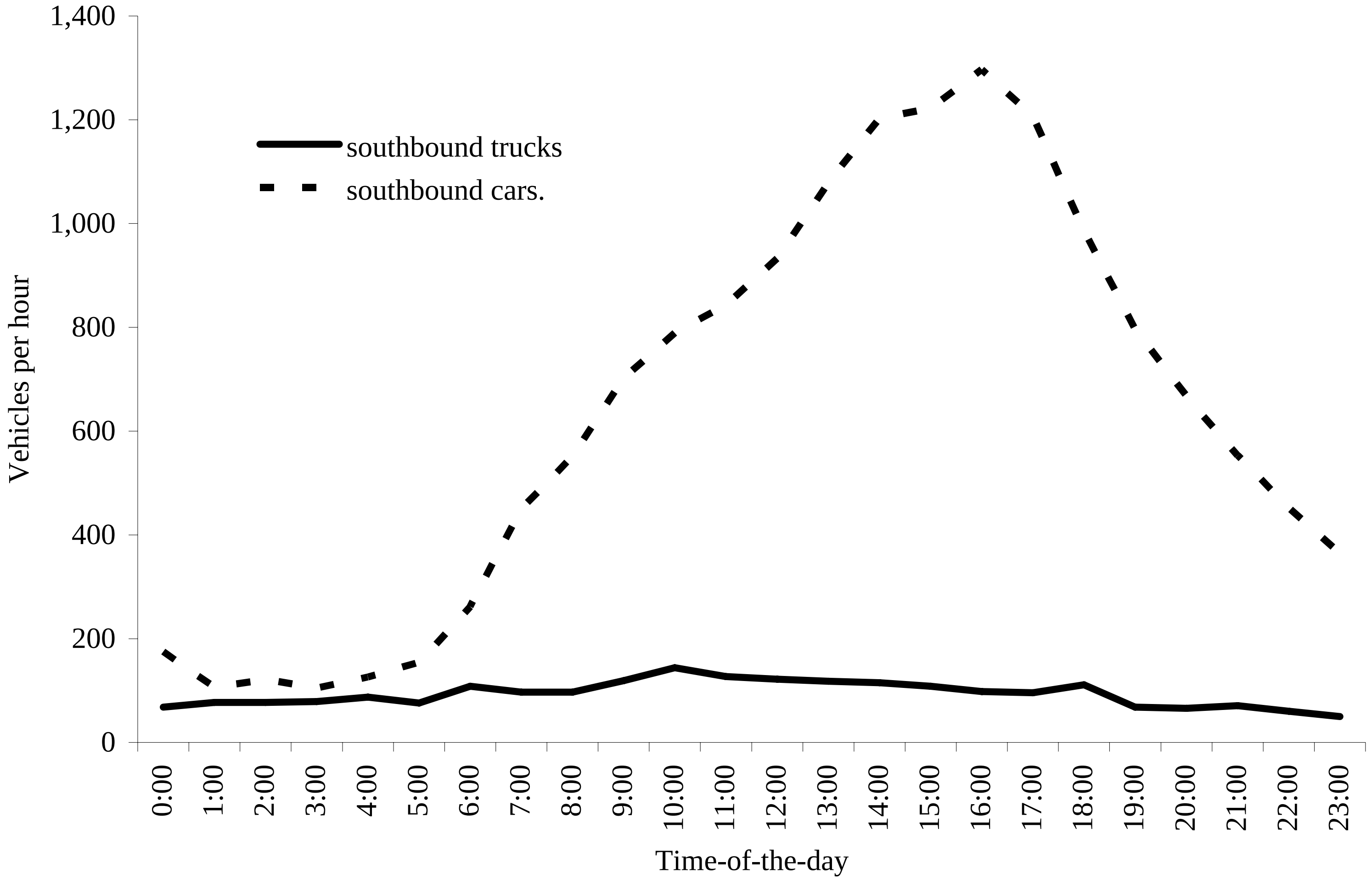


FIGURE B.2: Hourly Variation of Traffic on the Southbound Middle Lane at Milepost 374.

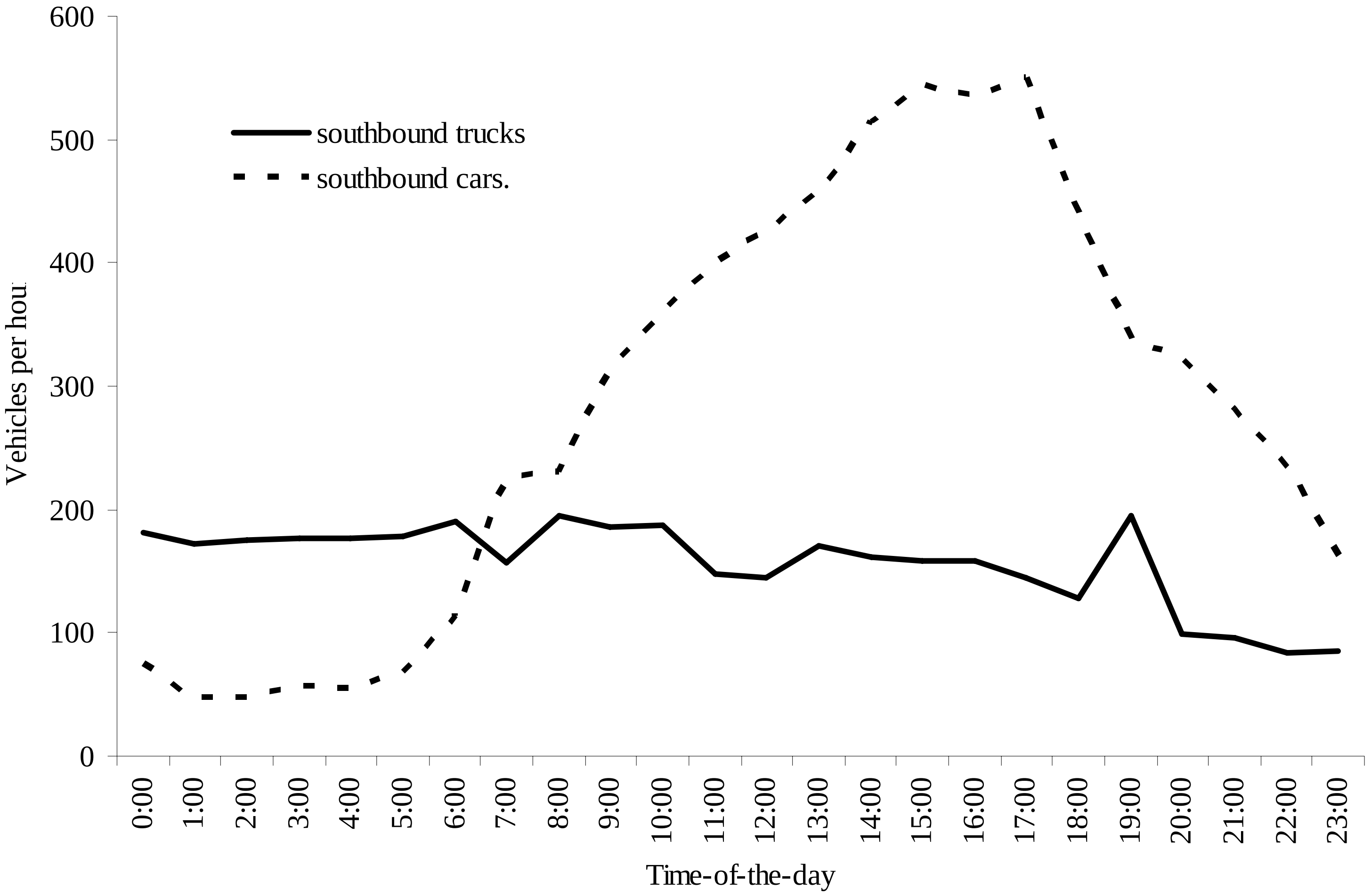


FIGURE B.3: Hourly variation of traffic on the Southbound Outside Lane at Milepost 374

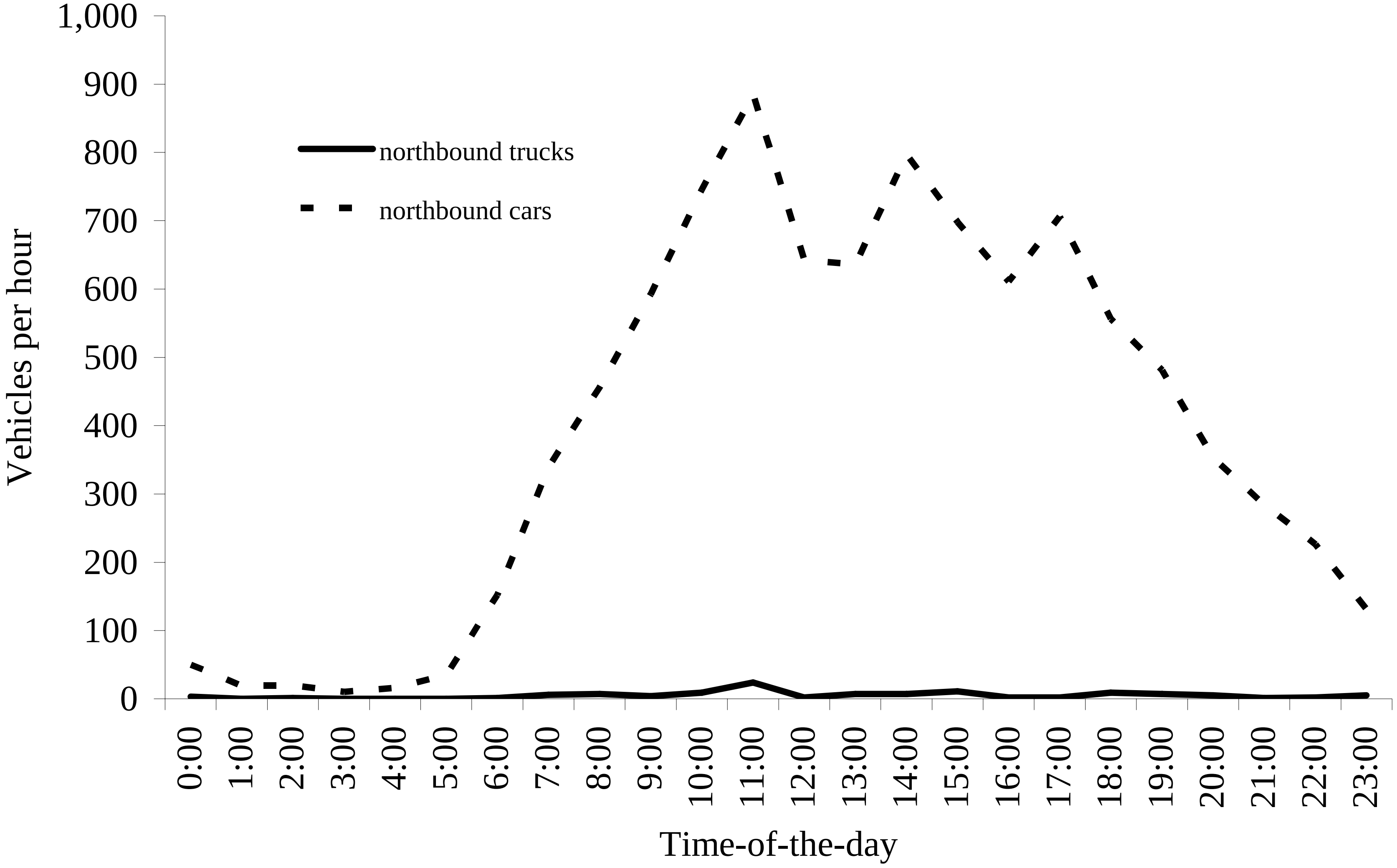


FIGURE B.4: Hourly Variation of Traffic on the Northbound Inside Lane at Milepost 374

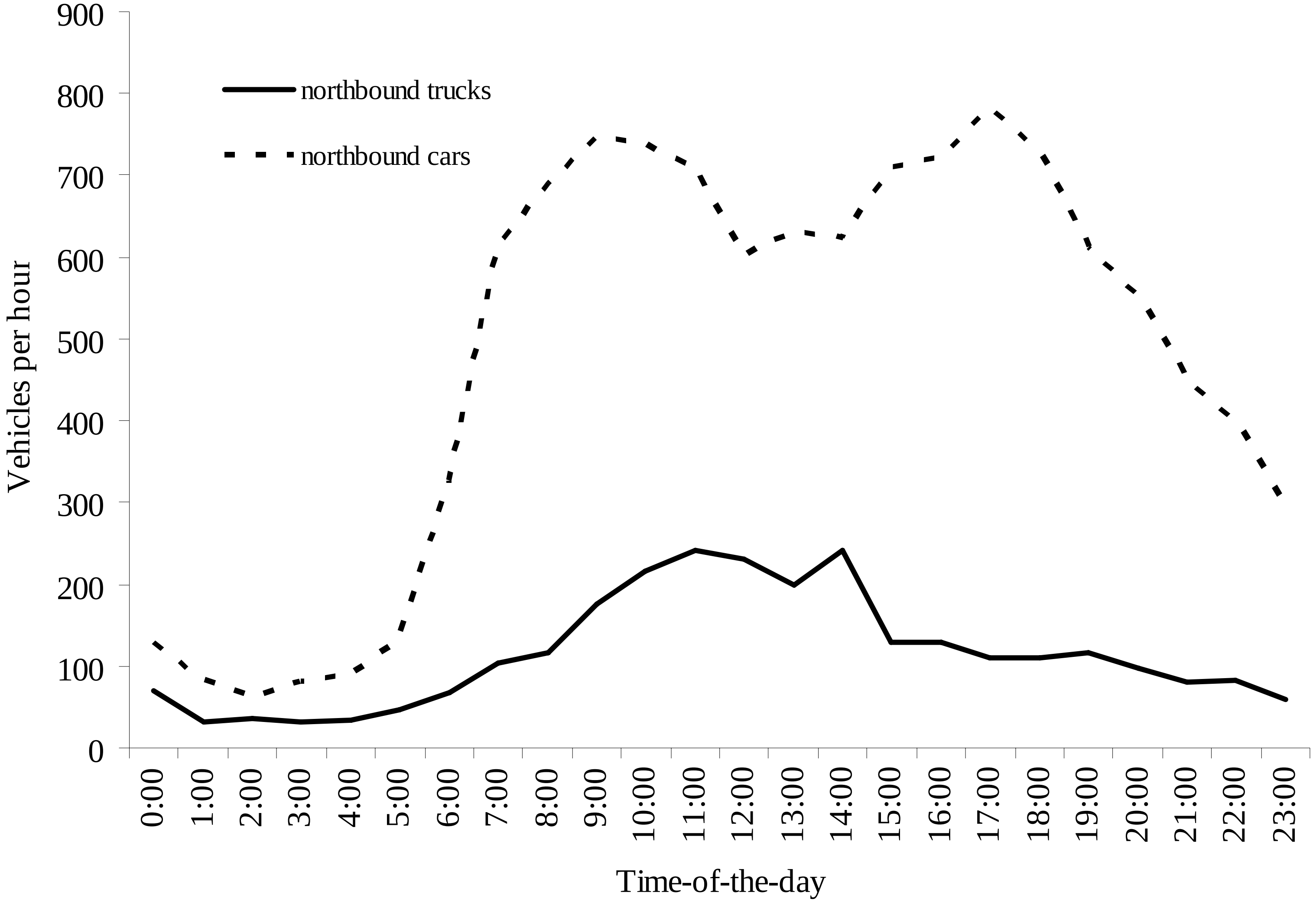


FIGURE B.5: Hourly Variation of Traffic on the Northbound Middle Lane at Milepost 374

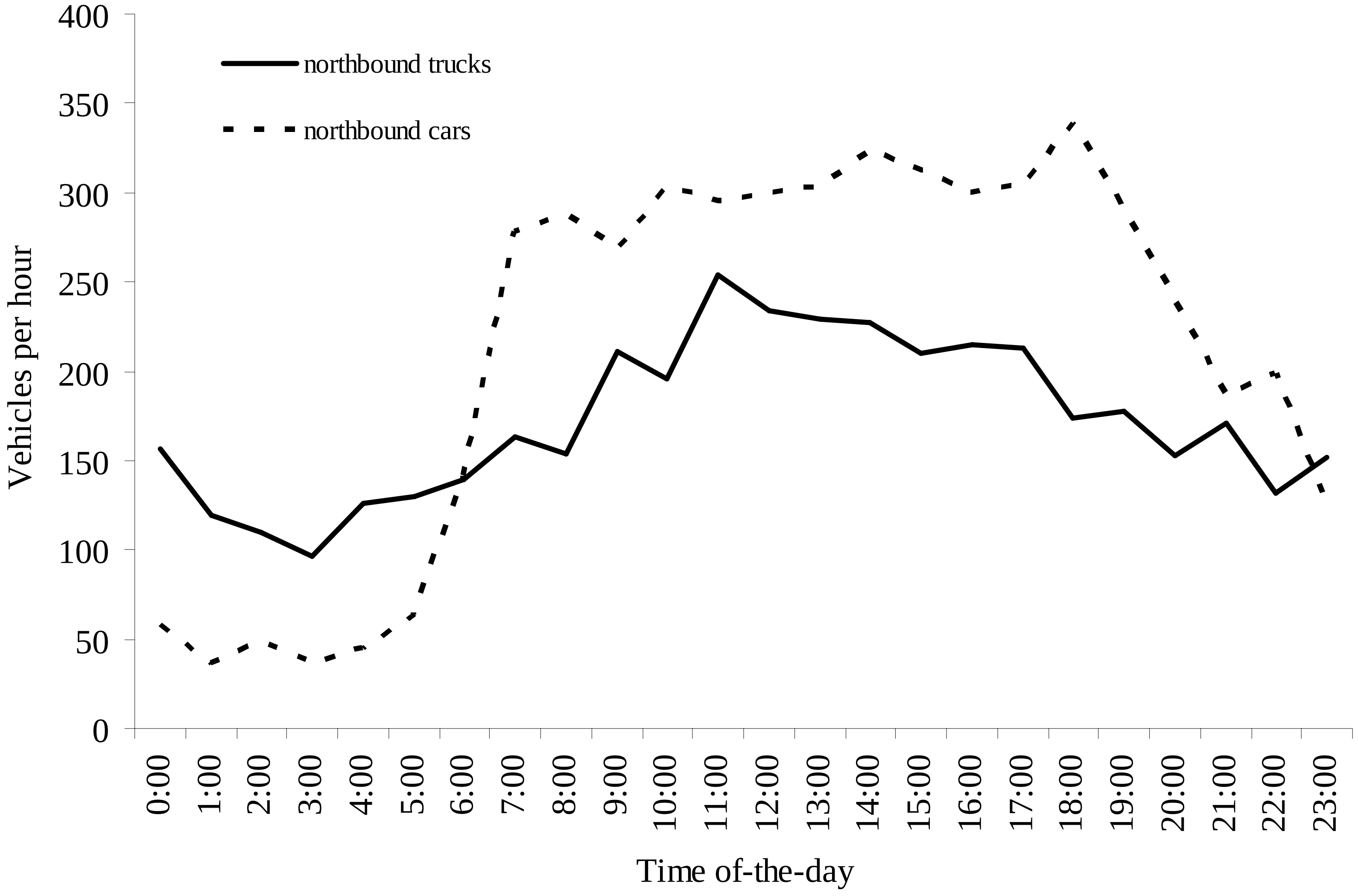


FIGURE B 6: Hourly Variation of Traffic in the Northbound Outside Lane at Milepost 374

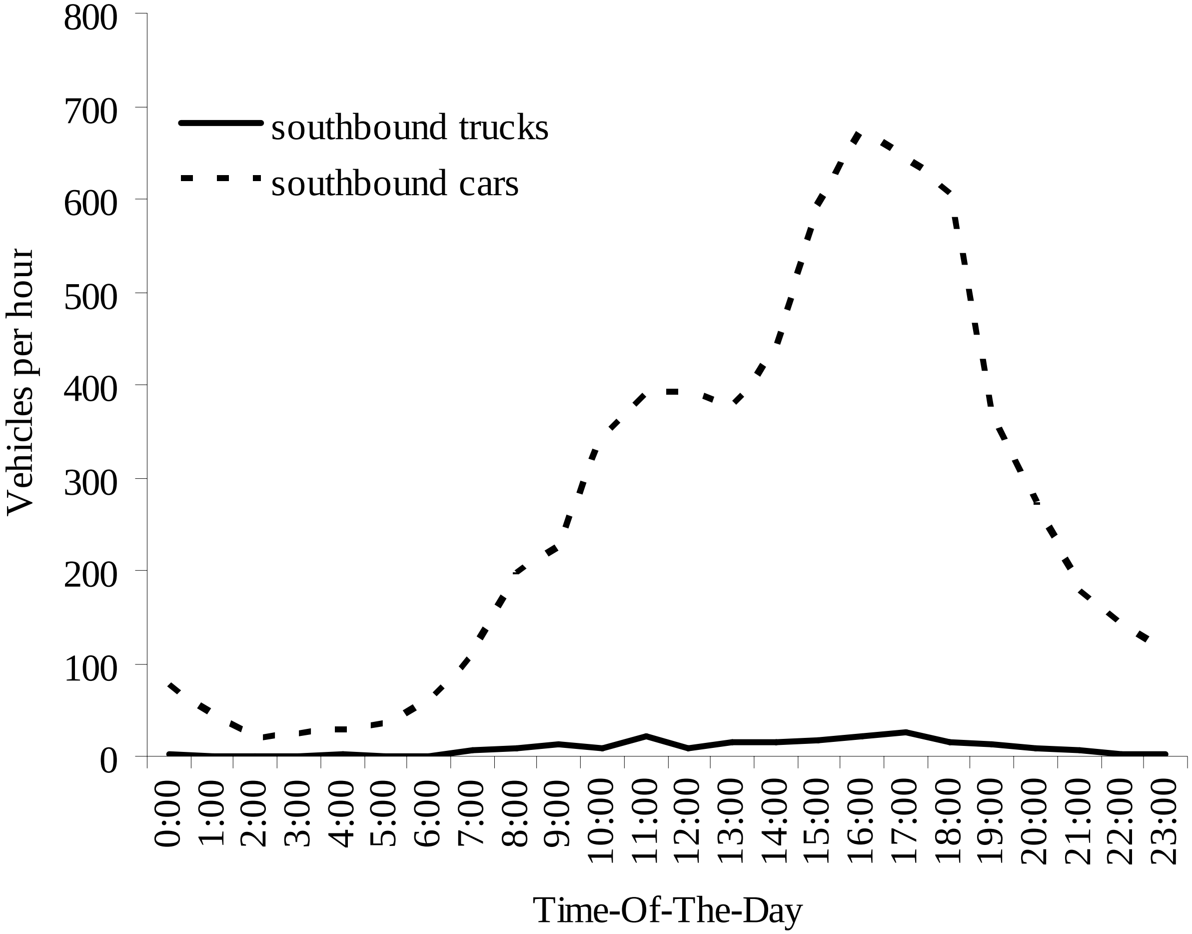


FIGURE B.7: Hourly Variation of Traffic in the Southbound Inside Lane at Milepost 428.

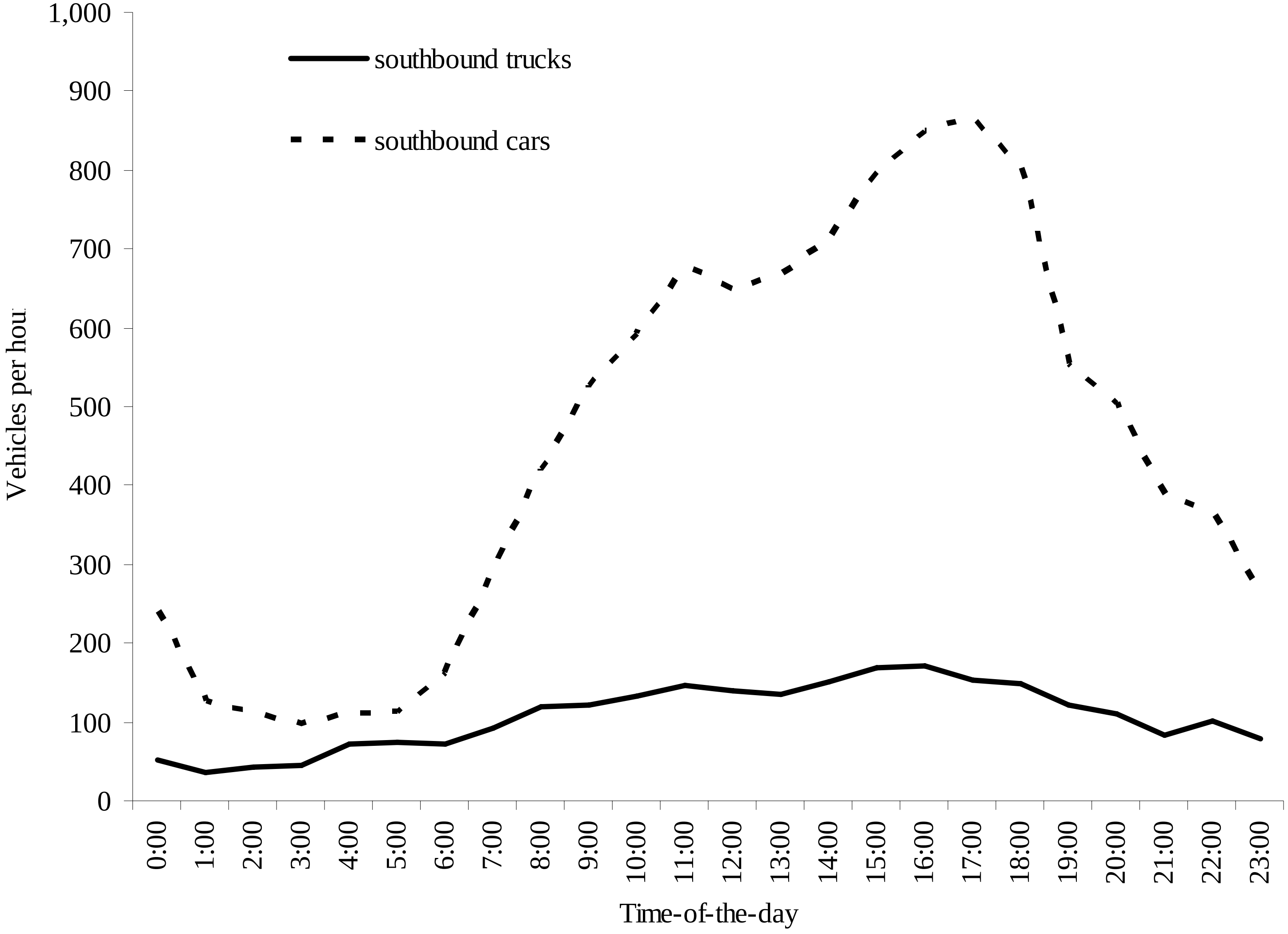


FIGURE B.8: Hourly Variation of Traffic on the Southbound Middle Lane at Milepost 428

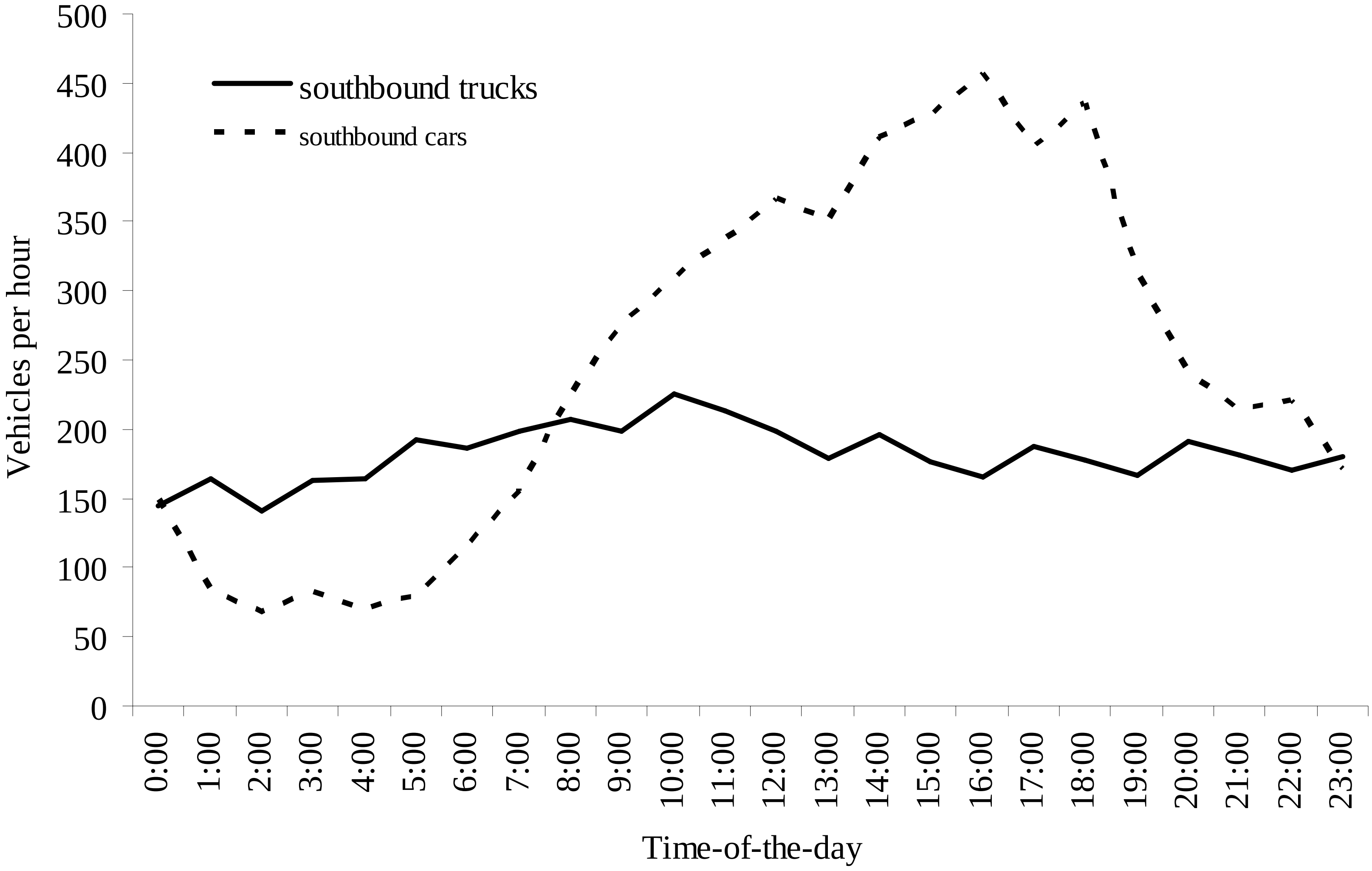


FIGURE B.9: Hourly Variation of Traffic on the Southbound Outside Lane at Milepost 428

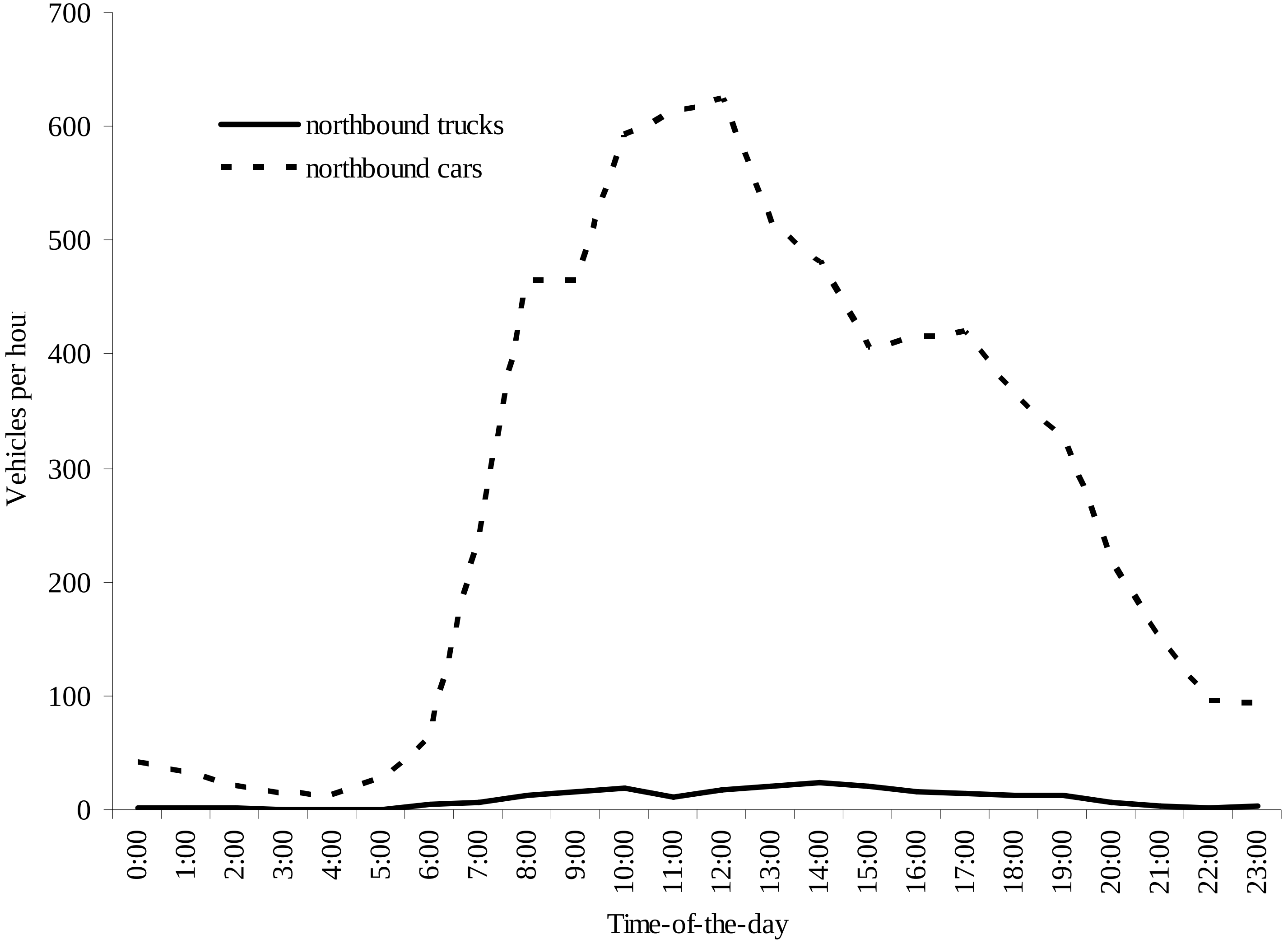


FIGURE B.10: Hourly Variation of Traffic on the Northbound Inside Lane at Milepost 428

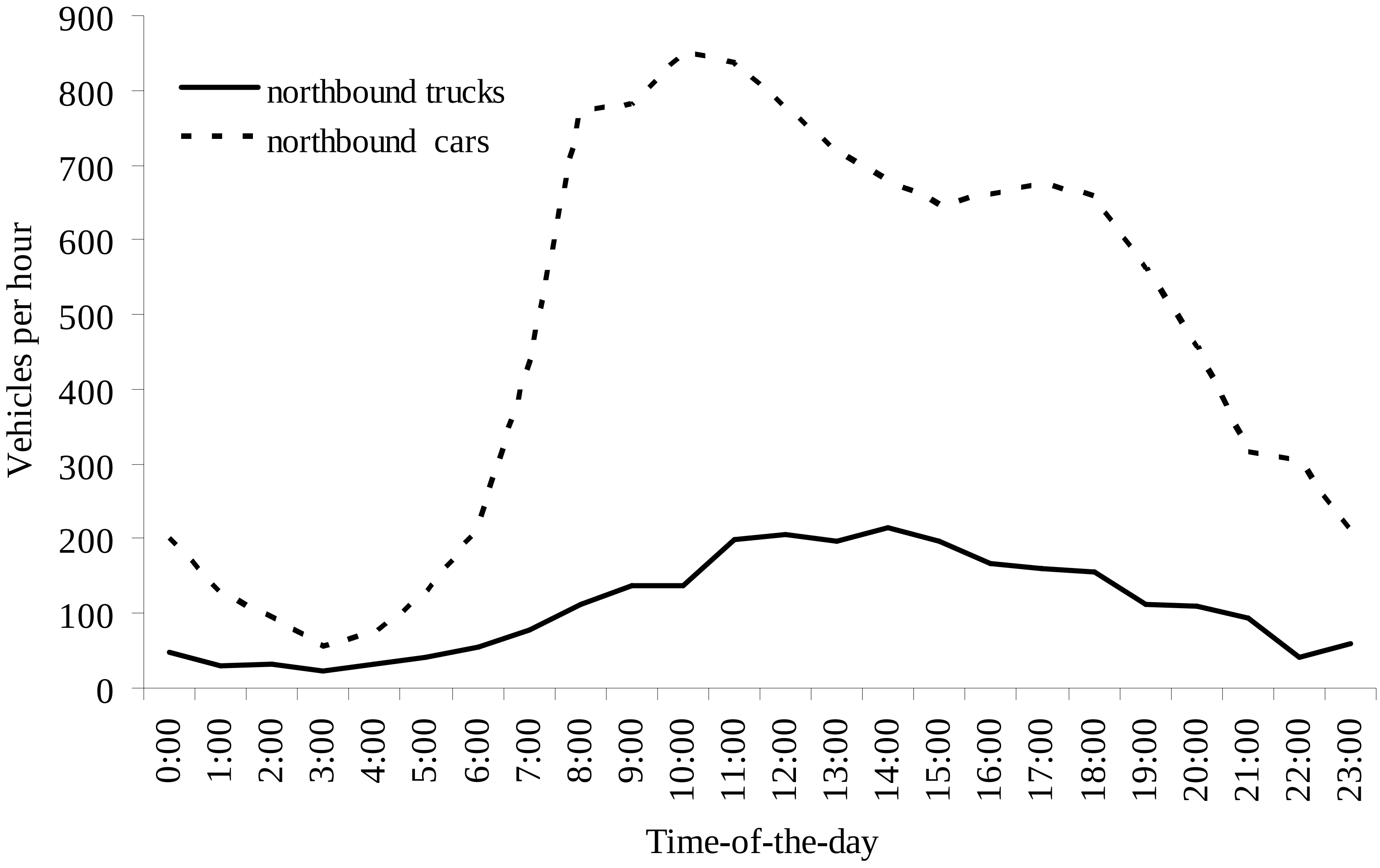


FIGURE B.11: Hourly Variation of Traffic on the Northbound Middle Lane at Milepost 428

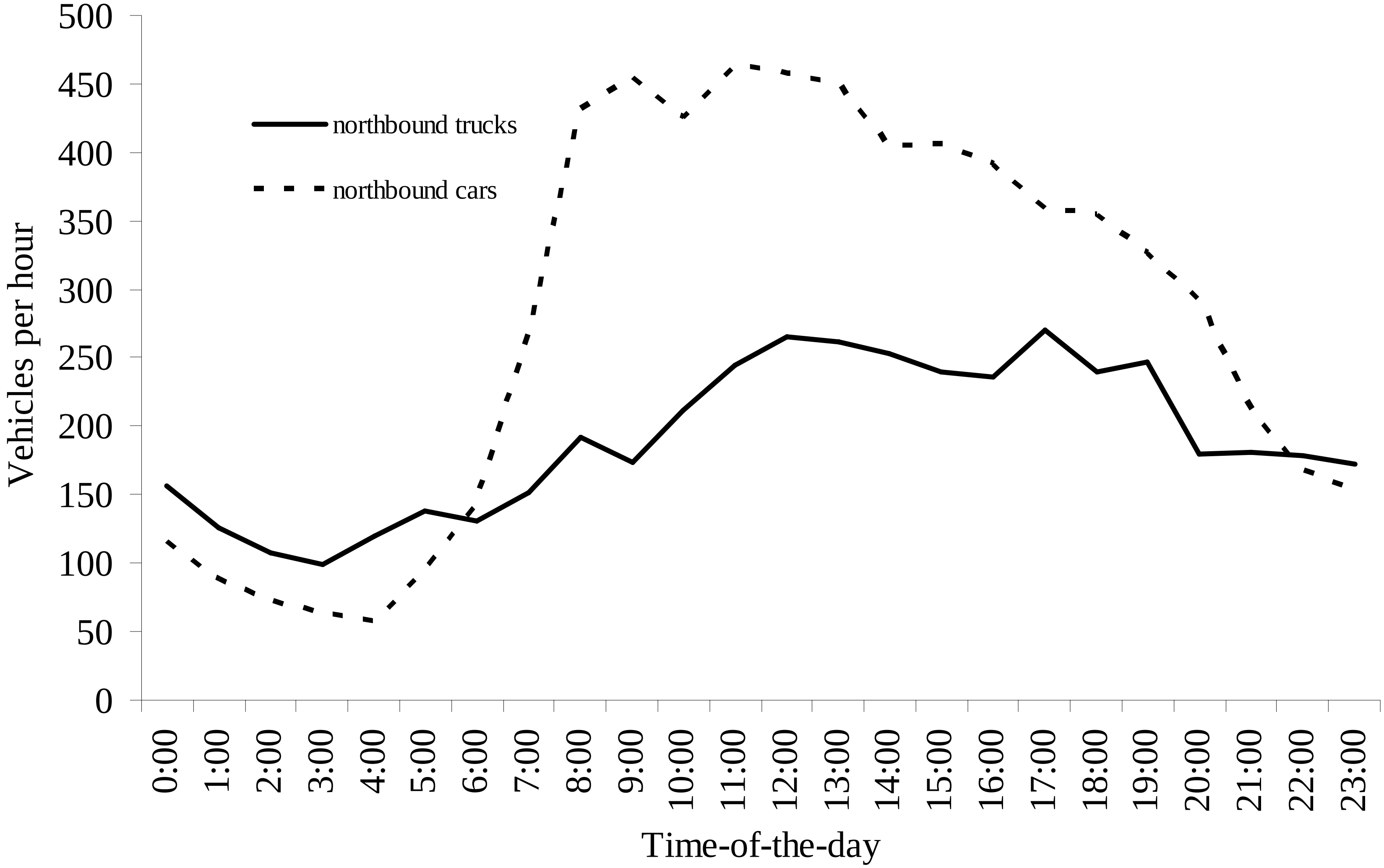


FIGURE B.12: Hourly Variation of Traffic on the Northbound Outside Lane at Milepost 428.

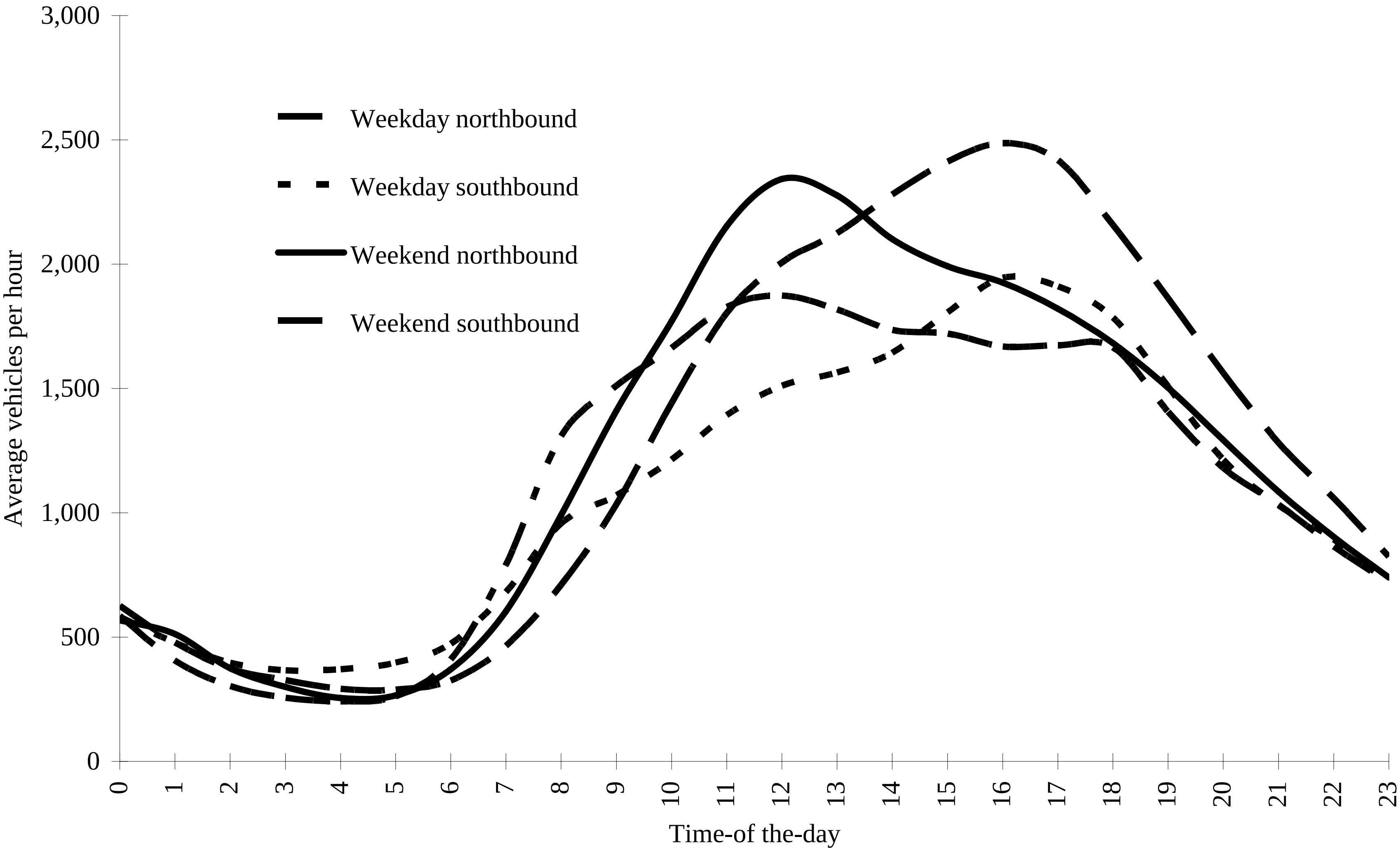


FIGURE B.13: Average Hourly Traffic Variation at Milepost 374 for Year 2001

APPENDIX C

HOURLY TRAFFIC VOLUME TABLES

TABLE C.1: The 24-hr Traffic Volume in the Southbound Direction at Milepost 374.

Time	DIRECTION: SOUTHBOUND							
	Inside lane (RESTRICTED)		Middle lane (UNRESTRICTED)		Outside lane (UNRESTRICTED)			
	Trucks	Passenger Cars	Trucks	Passenger Cars	Trucks	Passenger Cars	Total Trucks	Total passenger Cars
0:00	4	67	68	175	181	75	**253**	**317**
1:00	1	49	77	106	172	47	**250**	**202**
2:00	1	38	77	121	175	47	**253**	**206**
3:00	2	37	79	105	177	57	**258**	**199**
4:00	0	55	87	126	177	55	**264**	**236**
5:00	0	62	76	154	178	69	**254**	**285**
6:00	2	142	108	262	190	114	**300**	**518**
7:00	0	204	97	450	157	225	**254**	**879**
8:00	1	302	97	551	195	230	**293**	**1083**
9:00	2	399	119	702	186	314	**307**	**1415**
10:00	6	551	144	789	188	361	**338**	**1701**
11:00	5	708	127	843	148	401	**280**	**1952**
12:00	6	693	122	933	145	426	**273**	**2052**
13:00	7	724	118	1079	170	458	**295**	**2261**
14:00	11	783	115	1203	161	515	**287**	**2501**
15:00	12	777	108	1222	158	543	**278**	**2542**
16:00	9	774	98	1297	158	534	**265**	**2605**
17:00	11	728	96	1207	144	549	**251**	**2484**
18:00	8	689	111	985	128	439	**247**	**2113**
19:00	4	523	68	796	195	336	**267**	**1655**
20:00	1	407	66	667	99	323	**166**	**1397**
21:00	4	314	71	553	96	281	**171**	**1148**
22:00	1	213	60	452	83	235	**144**	**900**
23:00	2	167	50	365	86	162	**138**	**694**
24-hr total	**100**	**9,406**	**2,239**	**15,143**	**3,747**	**6,796**	**6,086**	**31,345**

TABLE C.2: The 24-hr Traffic Volume in the Northbound Direction at Milepost 374

Time	DIRECTION: NORTHBOUND							
	Inside lane (RESTRICTED)		Middle lane (UNRESTRICTED)		Outside lane (UNRESTRICTED)			
	Trucks	Passenger Cars	Trucks	Passenger Cars	Trucks	Passenger Cars	Total Trucks	Total passenger Cars
0:00	3	50	69	129	157	58	**229**	**237**
1:00	0	19	31	83	119	36	**150**	**138**
2:00	1	20	36	62	110	49	**147**	**131**
3:00	0	10	31	80	96	36	**127**	**126**
4:00	0	16	33	89	126	45	**159**	**150**
5:00	0	35	47	133	130	64	**177**	**232**
6:00	1	152	68	327	139	141	**208**	**620**
7:00	6	339	103	615	163	278	**272**	**1232**
8:00	7	456	117	690	154	287	**278**	**1433**
9:00	4	592	176	748	211	268	**391**	**1608**
10:00	9	745	217	736	196	304	**422**	**1785**
11:00	24	885	242	707	254	295	**520**	**1887**
12:00	2	642	230	602	234	300	**466**	**1544**
13:00	7	636	185	631	229	304	**421**	**1571**
14:00	7	797	241	623	227	324	**475**	**1744**
15:00	11	698	130	709	210	312	**351**	**1719**
16:00	2	611	130	723	215	300	**347**	**1634**
17:00	2	706	110	783	213	305	**325**	**1794**
18:00	9	556	110	729	174	339	**293**	**1624**
19:00	7	481	116	613	178	289	**301**	**1383**
20:00	5	353	97	552	153	240	**255**	**1145**
21:00	1	284	81	449	171	186	**253**	**919**
22:00	2	226	82	400	132	199	**216**	**825**
23:00	5	131	60	292	152	124	**217**	**547**
24-hr total	**115**	**9,440**	**2,757**	**11,505**	**4,143**	**5,083**	**7,015**	**26,028**

TABLE C.3: The 24-hr Traffic Volume in the Southbound Direction at Milepost 428

Time	**DIRECTION: SOUTHBOUND**							
	Inside lane (RESTRICTED)		**Middle lane (UNRESTRICTED)**		**Outside lane (UNRESTRICTED)**			
	Trucks	Passenger Cars	Trucks	Passenger Cars	Trucks	Passenger Cars	Total Trucks	Total passenger Cars
0:00	2	77	52	242	144	149	**198**	**468**
1:00	1	42	36	127	164	83	**201**	**252**
2:00	1	20	43	110	141	67	**185**	**197**
3:00	0	23	46	97	163	82	**209**	**202**
4:00	2	28	71	110	164	70	**237**	**208**
5:00	0	34	74	113	193	80	**267**	**227**
6:00	1	61	73	162	186	117	**260**	**340**
7:00	7	110	92	291	199	156	**298**	**557**
8:00	9	197	119	421	207	226	**335**	**844**
9:00	13	224	122	526	198	276	**333**	**1026**
10:00	9	345	133	593	226	310	**368**	**1248**
11:00	21	391	146	678	213	337	**380**	**1406**
12:00	9	391	140	648	198	367	**347**	**1406**
13:00	16	377	136	666	179	351	**331**	**1394**
14:00	14	436	151	715	196	411	**361**	**1562**
15:00	17	594	169	797	176	428	**362**	**1819**
16:00	22	673	172	850	166	457	**360**	**1980**
17:00	25	645	154	868	188	404	**367**	**1917**
18:00	15	607	149	803	178	435	**342**	**1845**
19:00	12	366	121	553	167	312	**300**	**1231**
20:00	8	273	110	504	191	240	**309**	**1017**
21:00	7	178	83	388	181	215	**271**	**781**
22:00	2	141	101	365	170	220	**273**	**726**
23:00	3	113	78	261	180	171	**261**	**545**
24-hr total	**216**	**6,346**	**2,571**	**10,888**	**4,368**	**5,964**	**7,155**	**23,198**

TABLE C.4: The 24-hr Traffic Volume in the Northbound Direction at Milepost 428

Time	**DIRECTION: NORTHBOUND**							
	Inside lane (RESTRICTED)		**Middle lane (UNRESTRICTED)**		**Outside lane (UNRESTRICTED)**			
	Trucks	Passenger Cars	Trucks	Passenger Cars	Trucks	Passenger Cars	**Total Trucks**	**Total passenger Cars**
0:00	2	41	47	201	156	116	**205**	**358**
1:00	1	32	30	129	126	88	**157**	**249**
2:00	1	20	33	93	107	72	**141**	**185**
3:00	0	15	22	55	99	63	**121**	**133**
4:00	0	13	31	74	120	57	**151**	**144**
5:00	0	27	40	128	138	95	**178**	**250**
6:00	4	65	54	214	131	144	**189**	**423**
7:00	6	239	77	431	152	266	**235**	**936**
8:00	12	464	111	772	192	431	**315**	**1667**
9:00	16	464	137	781	173	455	**326**	**1700**
10:00	19	593	138	852	211	425	**368**	**1870**
11:00	11	611	198	836	245	463	**454**	**1910**
12:00	18	624	206	780	265	457	**489**	**1861**
13:00	20	515	196	720	262	450	**478**	**1685**
14:00	23	482	214	678	253	405	**490**	**1565**
15:00	21	406	196	646	239	406	**456**	**1458**
16:00	16	413	167	660	236	391	**419**	**1464**
17:00	15	420	159	675	270	360	**444**	**1455**
18:00	12	364	155	658	240	355	**407**	**1377**
19:00	12	326	112	561	247	327	**371**	**1214**
20:00	6	217	110	457	180	292	**296**	**966**
21:00	3	150	94	316	181	211	**278**	**677**
22:00	1	95	41	303	179	167	**221**	**565**
23:00	3	94	60	210	172	151	**235**	**455**
24-hr total	**222**	**6,690**	**2,628**	**11,230**	**4,574**	**6,647**	**7,424**	**24,567**

APPENDIX D

CUMULATIVE HEADWAY DISTRIBUTION GRAPHS

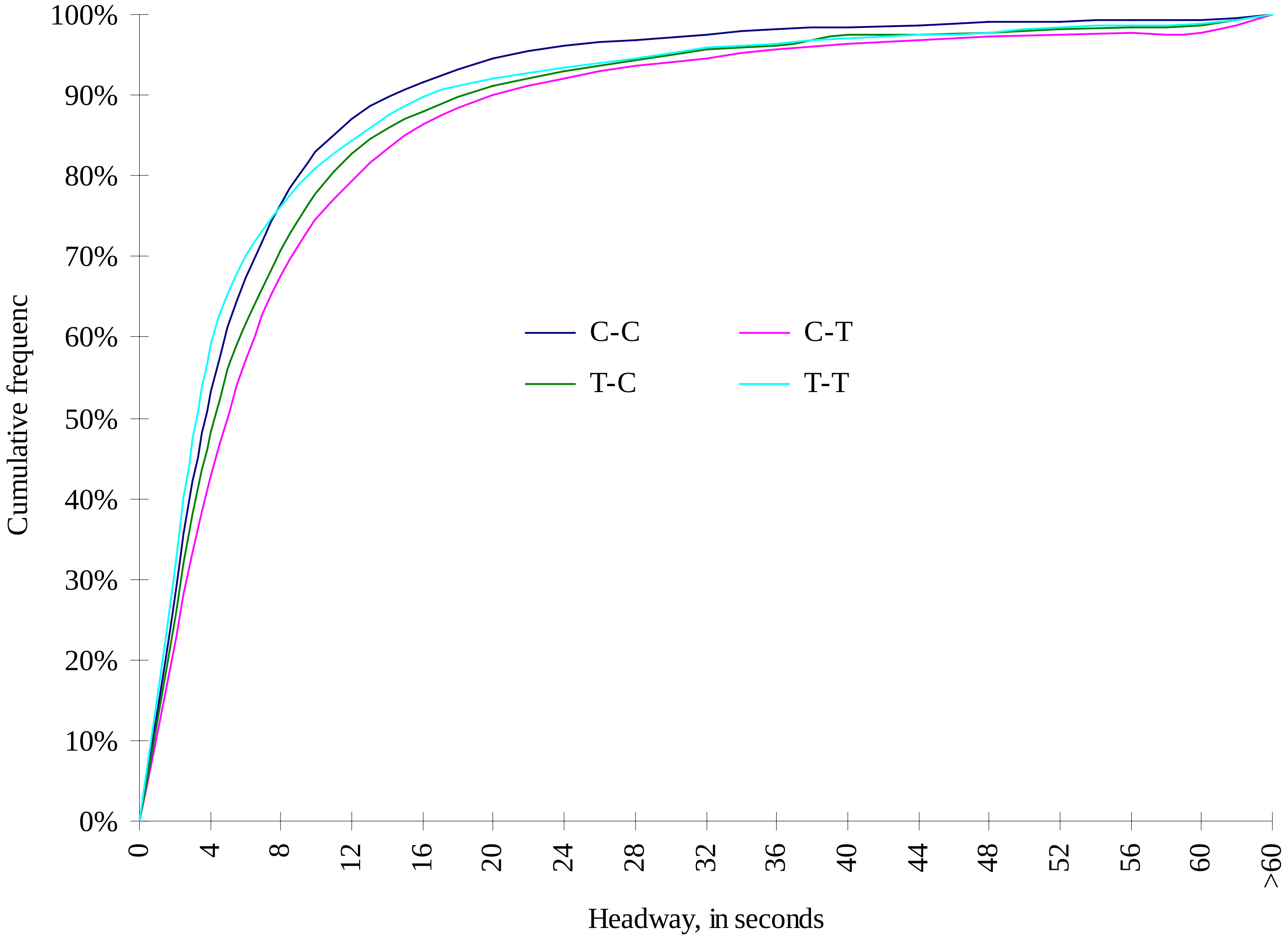


FIGURE D.1: Cumulative Headway Distribution in the Southbound Middle Lane at MP 428

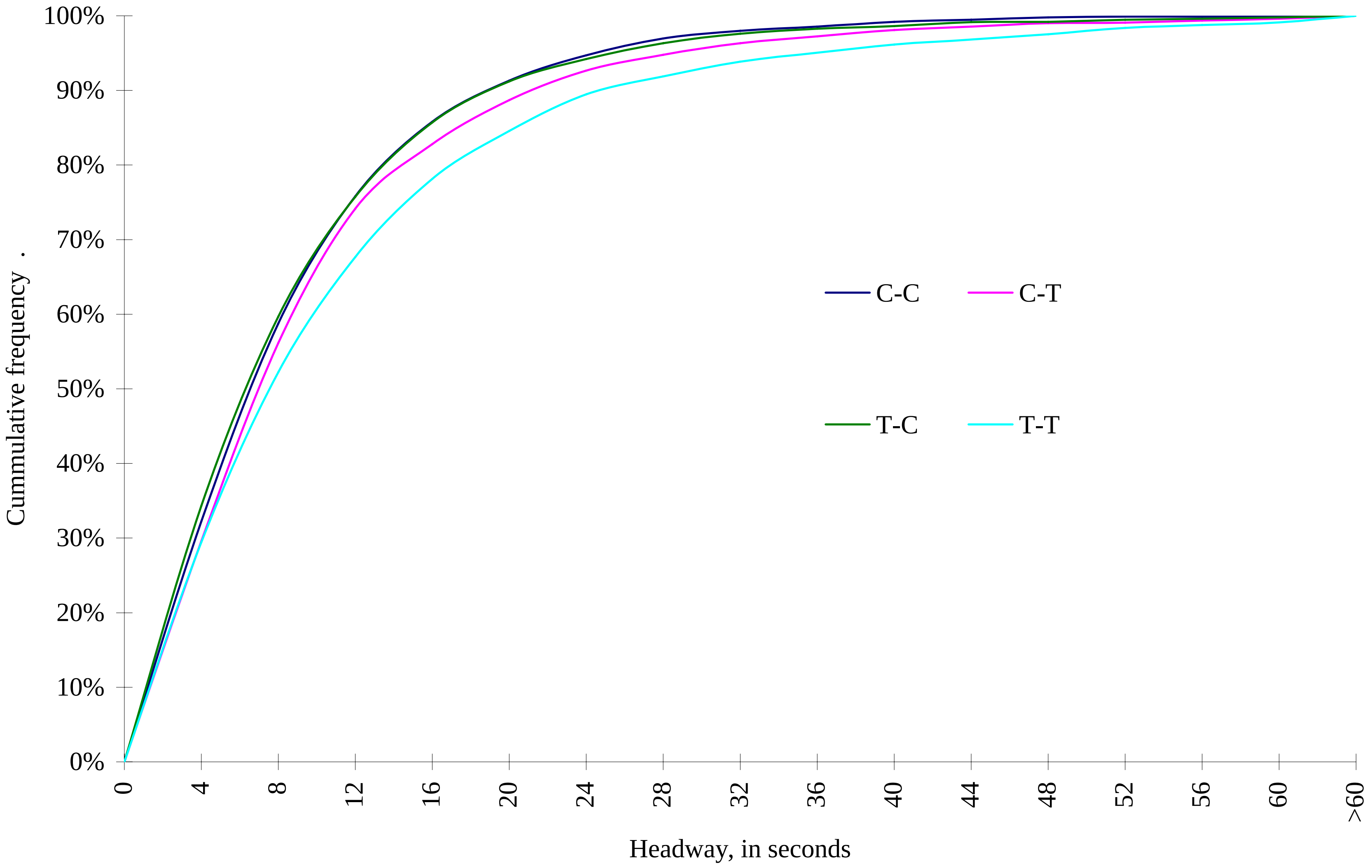


FIGURE D.2: Cumulative Headway Distribution in the Southbound Outside Lane at MP 428

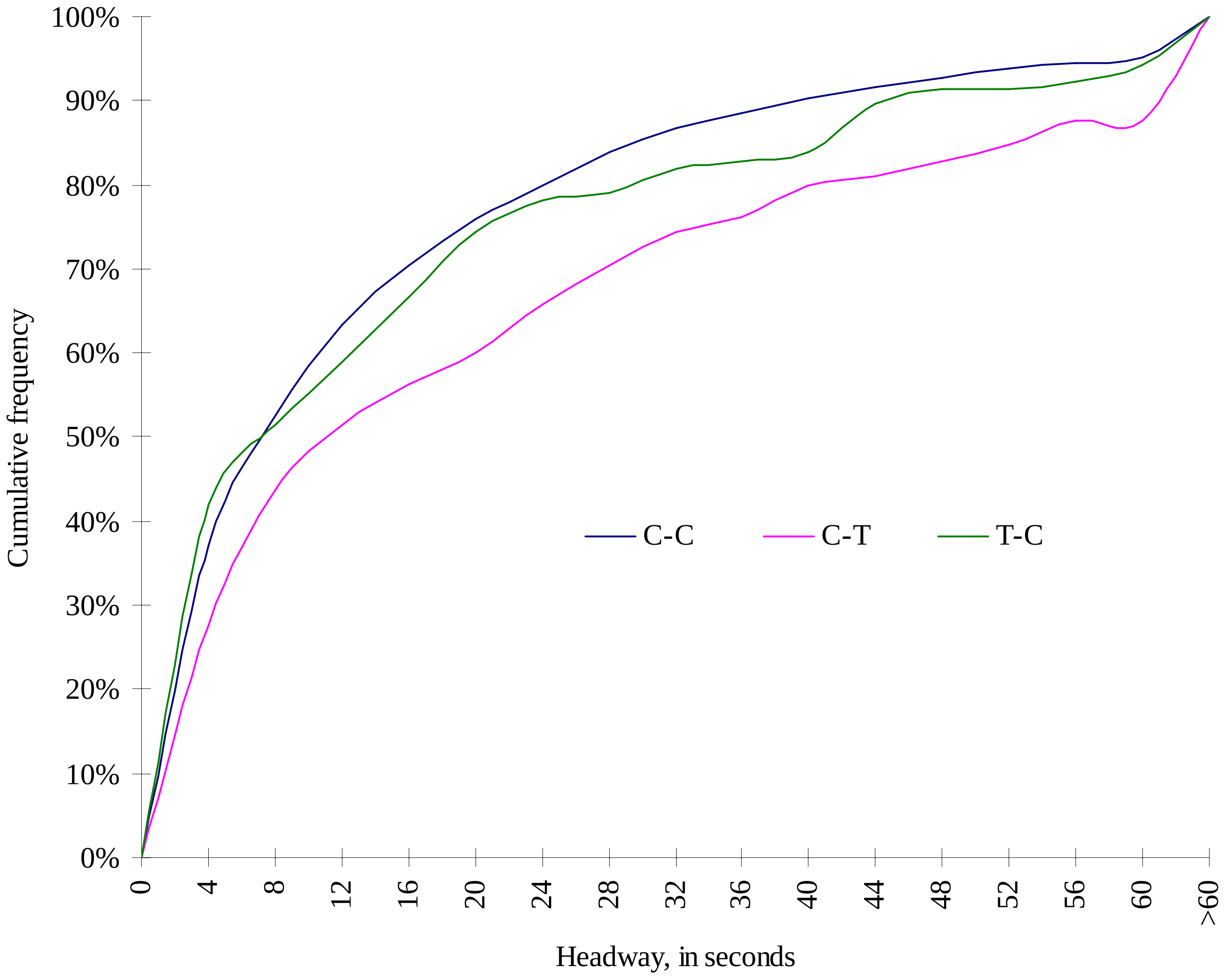


FIGURE D.3: Cumulative Headway Distribution in the Southbound Inside Lane at MP 428

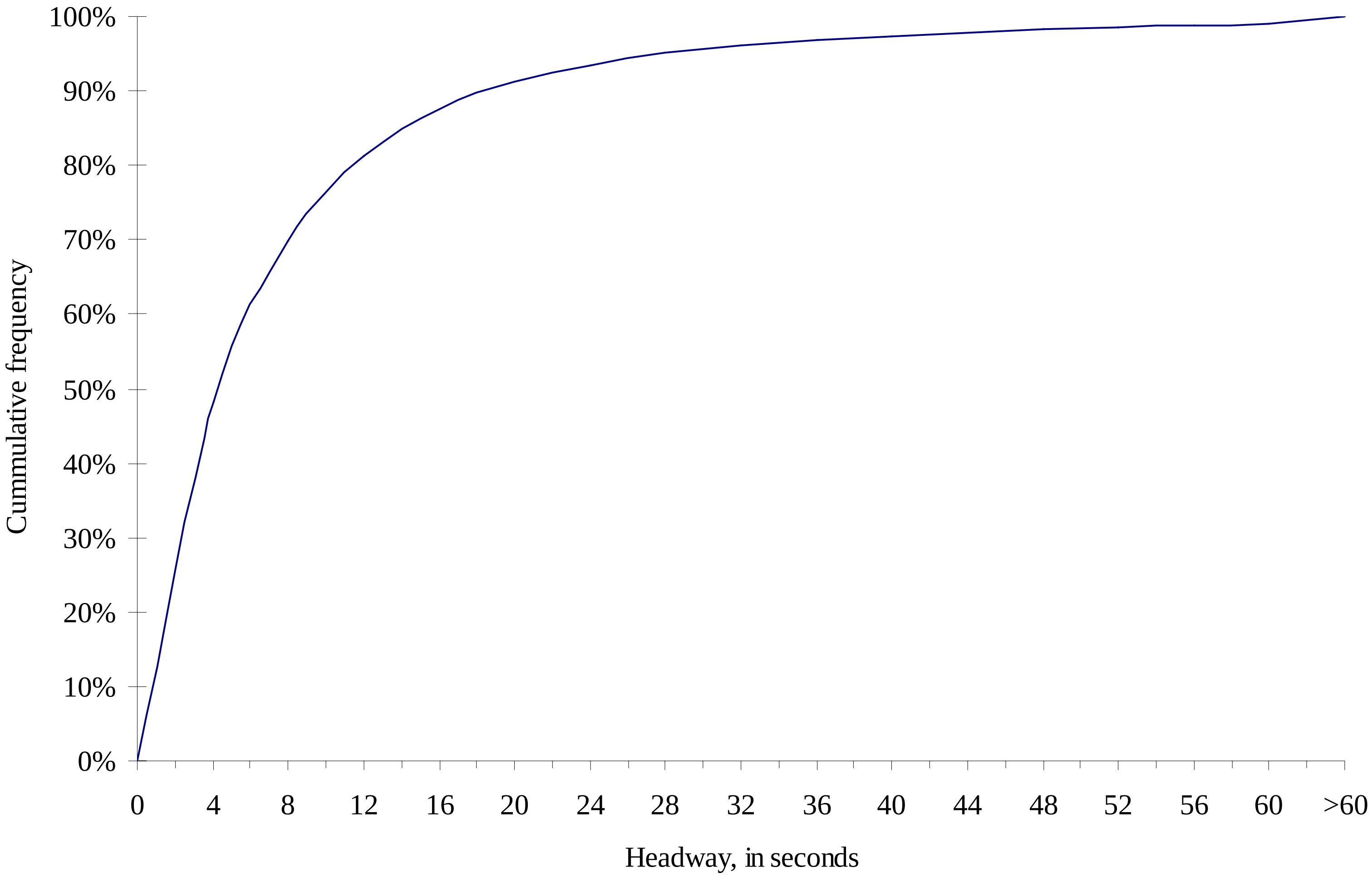


FIGURE D.4: Cumulative distribution of all headways at MP 428

APPENDIX E

RELATIONSHIP BETWEEN HEADWAY AND SPEED

TABLE E.1: Speed-Headway Relationship on Northbound Lanes at MP 374

SPEED (mph)	**INSIDE LANE**			**MIDDLE LANE**				**OUTSIDE LANE**			
	C-C	**C-T**	**T-C**	**C-C**	**C-T**	**T-C**	**T-T**	**C-C**	**C-T**	**T-C**	**T-T**
50-60				5.6 (3.7) *(15)*	8.5 (8.9) *(5)*	6.4 (5.8) *(17)*	6.4 (4.3) *(13)*	8.0 (7.4) *(101)*	10.1 (11.2) *(118)*	8.3 (7.7) *(122)*	11.6 (12.4) *(92)*
60-70	16.3 (20.4) *(386)*	12.4 (9.0) *(12)*	6.1 (6.0) *(18)*	6.9 (8.1) *(1,103)*	9.3 (12.8) *(481)*	8.7 (13.0) *(731)*	11.0 (15.3) *(587)*	8.9 (7.6) *(1,025)*	9.9 (9.5) *(926)*	9.5 (8.3) *(1,241)*	12.2 (12.3) *(2,177)*
70-80	15.7 (22.5) *(3,544)*	18.0 (18.7) *(87)*	15.0 (16.2) *(77)*	7.2 (8.2) *(4,254)*	9.2 (11.9) *(1,398)*	8.3 (10.7) *(1,141)*	10.3 (13.8) *(850)*	9.8 (7.8) *(862)*	10.6 (8.7) *(717)*	10.2 (8.8) *(373)*	11.4 (11.2) *(591)*
80-90	14.5 (16.4) *(554)*	6.4 (5.7) *(39)*	20.3 (14.6) *(10)*	7.5 (7.1) *(410)*	7.8 (7.4) *(131)*	5.8 (5.7) *(58)*	8.3 (8.0) *(39)*	8.0 (6.1) *(61)*	13.0 (10.2) *(54)*	10.7 (3.5) *(62)*	6.8 (5.5) *(7)*
90-100	14.3 (8.4) *(14)*			11.8 (6.8) *(11)*				10.8 (5.3) *(6)*	10.3 (4.2) *(5)*		12.7 (12.1) *(5)*

TABLE E.2: Speed-Headway Relationship on the Northbound Lanes at Milepost 428

SPEED (mph)	**INSIDE LANE**			**MIDDLE LANE**				**OUTSIDE LANE**			
	C-C	**C-T**	**T-C**	**C-C**	**C-T**	**T-C**	**T-T**	**C-C**	**C-T**	**T-C**	**T-T**
50-60				12.8 (8.0) *(7)*	6.8 (5.4) *(6)*	6.1 (5.8) *(7)*	3.7 (3.1) *(10)*	9.1 (7.4) *(68)*	10.2 (8.7) *(99)*	10.3 (8.5) *(107)*	10.4 (6.0) *(184)*
60-70	14.8 (14.4) *(197)*			8.0 (9.2) *(553)*	10.4 (12.2) *(244)*	9.6 (11.0) *(363)*	10.2 (12.7) *(299)*	8.5 (8.4) *(414)*	10.6 (10.4) *(466)*	11.0 (9.8) *(628)*	12.6 (12.1) *(1,072)*
70-80	18.3 (16.2) *(1,654)*	15.9 (19.4) *(42)*	12.14 (10.8) *(39)*	7.3 (8.6) *(2,132)*	10.1 (11.8) *(708)*	8.1 (9.9) *(569)*	9.1 (11.2) *(433)*	8.9 (8.1) *(433)*	10.7 (8.9) *(362)*	10.2 (9.2) *(194)*	11.4 (10.5) *(276)*
80-90	16.32 (20.6) *(289)*	12.8 (10.2) *(6)*	8.6 (6.5) *(7)*	7.6 (7.7) *(212)*	10.1 (9.6) *(68)*	5.6 (5.2) *(32)*	8.0 (7.7) *(24)*	9.1 (6.7) *(35)*	11.5 (8.2) *(29)*	11.0 (8.5) *(7)*	10.7 (8.0) *(9)*
90-100	9.0 (7.8) *(8)*			6.1 (4.0) *(5)*				8.3 (5.8) *(6)*	12.8 (13.5) *(5)*		

TABLE E.3: Speed-Headway Relationship for Southbound Lanes at Milepost 428

SPEED (mph)	**INSIDE LANE**			**MIDDLE LANE**				**OUTSIDE LANE**			
	C-C	**C-T**	**T-C**	**C-C**	**C-T**	**T-C**	**T-T**	**C-C**	**C-T**	**T-C**	**T-T**
50-60						5.0 (3.6) *(12)*	8.0 (5.7) *(13)*	9.4 (9.3) *(92)*	8.2 (7.3) *(74)*	12.5 (12.1) *(113)*	11.8 (9.9) *(83)*
60-70	16.7 (20.1) *(284)*			8.2 (7.3) *(1,008)*	8.9 (9.5) *(264)*	10.8 (15.6) *(522)*	7.2 (8.0) *(259)*	9.0 (8.4) *(932)*	9.3 (8.7) *(813)*	11.3 (10.6) *(715)*	11.6 (11.5) *(1,218)*
70-80	17.4 (35.6) *(1,624)*	12.2 (17.1) *(53)*	10.0 (10.3) *(62)*	9.3 (10.1) *(2,052)*	8.6 (10.5) *(1,132)*	8.1 (10.3) *(1,012)*	6.4 (8.3) *(538)*	9.0 (8.6) *(613)*	8.6 (9.2) *(509)*	10.0 (9.2) *(216)*	10.7 (9.9) *(312)*
80-90	15.5 (36.6) *(252)*	13.6 (16.5) *(5)*	10.4 (12.4) *(6)*	8.6 (9.4) *(234)*	9.0 (9.3) *(83)*	5.9 (6.3) *(46)*	10.6 (15.2) *(24)*	9.2 (7.2) *(37)*	9.4 (8.0) *(56)*	9.4 (9.0) *(6)*	9.6 (6.6) *(9)*
90-100	16.5 (21.8) (8)	8.5 (7.3) *(6)*	12.7 (11.2) *(8)*	9.2 (8.4) *(12)*	10.7 (6.1) *(5)*			5.0 (2.4) *(6)*	6.2 (3.6) *(5)*		

APPENDIX F

CORSIM RESULTS

TABLE F.1: CORSIM Output for Scenario 1 Involving Restricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	637	128.8	124.3	4.5	67.77
(3, 4)	525	128.3	123.8	4.5	68.00
(4, 6)	45	17.3	16.4	0.8	67.03
(5, 2)	23	16.8	16.4	0.3	69.12
(6, 23)	2,474	253.1	233.8	19.3	64.66
(7, 5)	864	215.8	209.5	6.3	68.38
(13, 6)	0	47.2	42.5	4.7	31.28
(15, 26)	1,341	142.4	130.5	11.9	64.14
(22, 7)	20	6.3	6.2	0.2	64.67
(23, 15)	40	7.4	6.8	0.6	64.69
(24, 2)	0	46.2	42.4	3.8	31.97
(25, 22)	672	139.5	133.5	6	67.44
(26, 87)	32	5.2	4.9	0.4	65.11
(31, 87)	0	3.3	3.2	0	34.73
(32, 25)	12	7.1	6.8	0.3	67.56
(41, 32)	1,253	268.8	253.5	15.3	66.54
(42, 41)	0	3.4	3.4	0	38.55
(43, 41)	21	5.1	4.8	0.3	66.25
(44, 46)	20	7.2	6.8	0.5	65.85
(46, 48)	710	135	127.4	7.6	66.22
(47, 43)	1,036	154.8	145.3	9.5	66.13
(48, 50)	13	6	5.8	0.2	68.27
(49, 47)	18	6.1	5.8	0.3	66.80
(50, 52)	862	133.2	127.9	5.3	67.14
(51, 49)	932	136.8	128.4	8.4	66.18
(52, 54)	11	6	5.8	0.2	68.13
(53, 51)	55	6.1	5.8	0.3	67.18
(54, 76)	1,441	265.9	256.4	9.6	67.25
(63, 46)	0	1	1	0	35.51
(65, 50)	0	3	3	0	34.68
(66, 47)	0	2.9	2.9	0	34.75
(71, 54)	0	3.4	3.4	0	34.61
(72, 51)	0	3	2.9	0	34.84
(73, 75)	7	5.9	5.7	0.1	68.96
(74, 84)	273	13.6	11.6	2	59.60
(75, 53)	1,441	219.4	208.8	10.6	67.12
(76, 74)	32	6.2	5.9	0.3	66.08
(81, 75)	0	2.9	2.9	0	34.88
(82, 74)	0	2.7	2.6	0	34.56
(83, 73)	180	12.3	11.8	0.5	67.97
(85, 7)	0	2.7	1.8	0.9	42.92
(86, 15)	0	2.6	1.8	0.9	43.11

TABLE F.2: CORSIM Output for Scenario 1 Involving Unrestricted Operation During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	617	129.8	125.4	4.5	67.23
(3, 4)	585	128.4	123.7	4.6	67.98
(4, 6)	76	17.2	16.4	0.8	67.46
(5, 2)	24	17	16.7	0.3	68.31
(6, 23)	2,748	251	232.2	18.9	65.19
(7, 5)	858	218.2	212.6	5.7	67.61
(13, 6)	0	47	42.1	4.9	31.41
(15, 26)	1,296	140	130	10	65.27
(22, 7)	14	6.4	6.3	0.1	63.97
(23, 15)	39	7.3	6.8	0.5	65.83
(24, 2)	0	45.8	42.3	3.5	32.28
(25, 22)	716	143.2	135.6	7.6	65.71
(26, 87)	48	5.3	4.8	0.4	64.62
(31, 87)	0	3.3	3.3	0	34.44
(32, 25)	29	7.3	6.9	0.4	65.69
(41, 32)	1,453	276	257	19	64.81
(42, 41)	0	3.5	3.4	0	37.97
(43, 41)	12	5.2	4.9	0.3	65.63
(44, 46)	22	7.2	6.8	0.4	66.22
(46, 48)	808	135.7	128.1	7.6	65.91
(47, 43)	1,133	156.6	146.9	9.7	65.36
(48, 50)	14	6	5.9	0.2	67.76
(49, 47)	24	6.1	5.9	0.3	66.68
(50, 52)	820	133.7	128.5	5.2	66.87
(51, 49)	992	137	129.6	7.3	66.1
(52, 54)	15	6	5.9	0.2	67.8
(53, 51)	28	6.1	5.8	0.3	66.76
(54, 76)	1,385	266.5	257.8	8.7	67.1
(63, 46)	0	1	1	0	35.21
(65, 50)	0	3	3	0	34.53
(66, 47)	0	3	2.9	0	34.61
(71, 54)	0	3.4	3.4	0	34.42
(72, 51)	0	3	3	0	34.51
(73, 75)	16	5.9	5.7	0.1	68.75
(74, 84)	273	13.4	11.7	1.7	60.56
(75, 53)	1,378	220.2	210.4	9.8	66.86
(76, 74)	28	6.1	5.9	0.2	67
(81, 75)	0	2.9	2.9	0	34.68
(82, 74)	0	2.7	2.7	0	34.27
(83, 73)	179	12.3	11.9	0.4	67.83
(85, 7)	0	2.7	1.8	0.9	42.76
(86, 15)	0	2.7	1.8	0.9	42.81

TABLE F.3: CORSIM Output for Scenario 2 Involving Restricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	534	131.8	125.3	6.5	66.2
(3, 4)	497	131.1	124.3	6.7	66.58
(4, 6)	48	17.8	16.5	1.3	65.12
(5, 2)	24	17.1	16.6	0.5	67.75
(6, 23)	2,074	282.7	233.8	48.9	57.88
(7, 5)	710	219.5	212	7.5	67.2
(13, 6)	0	45.6	42.1	3.4	32.43
(15, 26)	1,208	162.7	130.8	31.9	56.15
(22, 7)	14	6.4	6.3	0.2	63.68
(23, 15)	29	8.7	6.8	1.9	54.65
(24, 2)	0	44.9	42.4	2.5	32.9
(25, 22)	600	142.2	134.8	7.4	66.18
(26, 87)	41	7	4.9	2.1	49.04
(31, 87)	0	3.3	3.2	0.1	34.49
(32, 25)	14	7.4	6.9	0.5	65.36
(41, 32)	1,163	290.4	256	34.4	61.58
(42, 41)	0	3.5	3.5	0	37.38
(43, 41)	16	5.7	4.9	0.9	59.54
(44, 46)	25	7.3	6.8	0.4	65.63
(46, 48)	606	136.9	128	8.9	65.31
(47, 43)	948	163	146.2	16.8	62.76
(48, 50)	26	6.2	5.9	0.4	65.53
(49, 47)	19	6.3	5.8	0.5	64.72
(50, 52)	719	135.6	128.4	7.2	65.95
(51, 49)	988	143.2	129.1	14.1	63.22
(52, 54)	8	6.1	5.9	0.2	67.17
(53, 51)	60	6.3	5.8	0.4	65.25
(54, 76)	1,016	268.6	257.3	11.3	66.58
(63, 46)	0	1	1	0	35.38
(65, 50)	0	3	3	0	34.43
(66, 47)	0	2.9	2.9	0	34.69
(71, 54)	0	3.5	3.4	0.1	34.29
(72, 51)	0	3	2.9	0	34.65
(73, 75)	12	6	5.7	0.3	67.1
(74, 84)	295	14.9	11.7	3.2	54.45
(75, 53)	1,455	224.6	209.2	15.3	65.57
(76, 74)	39	6.4	5.9	0.5	63.63
(81, 75)	0	2.9	2.9	0	34.76
(82, 74)	0	2.7	2.6	0.1	33.71
(83, 73)	190	12.7	11.9	0.9	65.52
(85, 7)	0	2.7	1.8	0.9	42.51
(86, 15)	0	2.7	1.8	0.9	42.25

TABLE F.4: CORSIM Output for Scenario 2 Involving Unrestricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	478	130.5	125.5	5	66.87
(3, 4)	547	129.2	123.8	5.4	67.55
(4, 6)	70	17.4	16.4	1	66.52
(5, 2)	28	17	16.7	0.3	68.1
(6, 23)	2,466	280.2	232.9	47.3	58.4
(7, 5)	680	219.4	212.2	7.2	67.24
(13, 6)	0	45.5	42.1	3.4	32.45
(15, 26)	1,142	159.7	130.7	28.9	57.21
(22, 7)	23	6.5	6.3	0.2	63.16
(23, 15)	37	9.3	6.8	2.5	51.24
(24, 2)	0	44.9	42.5	2.4	32.92
(25, 22)	597	143.3	135.2	8.1	65.64
(26, 87)	29	6.3	4.9	1.4	54.1
(31, 87)	0	3.3	3.2	0.1	34.57
(32, 25)	16	7.3	6.9	0.4	65.57
(41, 32)	1,067	286.7	256.6	30.1	62.37
(42, 41)	0	3.5	3.5	0	37.49
(43, 41)	31	5.9	4.9	1	57.59
(44, 46)	16	7.3	6.8	0.5	65.33
(46, 48)	612	137	128.2	8.8	65.28
(47, 43)	875	163.6	146.4	17.2	62.53
(48, 50)	16	6.1	5.9	0.3	66.58
(49, 47)	34	6.4	5.8	0.6	63.77
(50, 52)	772	135.6	128.2	7.3	65.96
(51, 49)	989	142.4	129.1	13.3	63.58
(52, 54)	18	6.1	5.9	0.2	66.86
(53, 51)	31	6.3	5.8	0.5	65.2
(54, 76)	1,127	269.1	257.6	11.5	66.45
(63, 46)	0	1	1	0	35.28
(65, 50)	0	3	3	0.1	34.38
(66, 47)	0	2.9	2.9	0	34.73
(71, 54)	0	3.5	3.4	0.1	34.27
(72, 51)	0	3	2.9	0	34.65
(73, 75)	15	5.9	5.7	0.2	68.12
(74, 84)	281	14.4	11.7	2.7	56.36
(75, 53)	1,341	223.8	209.4	14.4	65.78
(76, 74)	41	6.3	5.9	0.4	65.08
(81, 75)	0	2.9	2.9	0	34.8
(82, 74)	0	2.7	2.6	0.1	33.59
(83, 73)	155	12.5	11.9	0.6	66.81
(85, 7)	0	2.7	1.8	0.9	42.51
(86, 15)	0	2.7	1.8	0.9	42.18

TABLE F.5: CORSIM Output for Scenario 3 Involving Restricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	375	135.5	126	9.4	64.43
(3, 4)	449	140.2	124.9	15.4	62.24
(4, 6)	99	25.8	16.6	9.2	44.97
(5, 2)	36	17.8	16.8	1	65.1
(6, 23)	946	343.6	242	101.6	47.62
(7, 5)	440	227.6	214.2	13.4	64.82
(13, 6)	0	61.6	42.6	19.1	23.98
(15, 26)	691	192.7	134.4	58.4	47.4
(22, 7)	24	6.8	6.4	0.4	60.72
(23, 15)	21	15.4	6.9	8.5	31.06
(24, 2)	0	45.7	42.4	3.3	32.34
(25, 22)	426	151.3	136.5	14.9	62.16
(26, 87)	38	9.2	4.9	4.3	37.23
(31, 87)	0	3.6	3.3	0.3	31.94
(32, 25)	24	8.5	6.9	1.5	56.77
(41, 32)	518	302.1	258.8	43.3	59.2
(42, 41)	0	3.6	3.5	0.1	36.31
(43, 41)	22	8.1	4.9	3.2	41.88
(44, 46)	28	8.3	6.9	1.4	57.78
(46, 48)	465	143.7	129.4	14.3	62.22
(47, 43)	583	194.6	148.1	46.5	52.58
(48, 50)	29	6.7	5.9	0.7	61.5
(49, 47)	28	9.4	5.9	3.5	43.42
(50, 52)	615	142.2	129.2	12.9	62.89
(51, 49)	764	178.6	130.7	47.9	50.69
(52, 54)	37	7.8	5.9	1.9	52.39
(53, 51)	70	10	5.8	4.1	41.08
(54, 76)	640	288.4	259.4	29	62.01
(63, 46)	0	1	1	0	34.59
(65, 50)	0	3.1	3	0.1	33.21
(66, 47)	0	3.1	2.9	0.1	33.28
(71, 54)	0	3.6	3.4	0.2	32.75
(72, 51)	0	3.3	3	0.3	31.29
(73, 75)	20	7.1	5.7	1.3	57.14
(74, 84)	280	17.4	11.8	5.6	46.66
(75, 53)	1,495	268.7	210.4	58.3	54.79
(76, 74)	103	7.4	5.9	1.5	55.18
(81, 75)	0	3	2.9	0.1	33.87
(82, 74)	0	2.9	2.7	0.2	31.93
(83, 73)	244	15.1	11.9	3.2	55.28
(85, 7)	0	2.7	1.8	0.9	42.55
(86, 15)	0	3.5	1.8	1.8	32.16

TABLE F.6: CORSIM Output for Scenario 3 Involving Unrestricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	398	135.7	125.9	9.8	64.31
(3, 4)	445	134.1	124	10.1	65.08
(4, 6)	70	20.5	16.5	4.1	56.47
(5, 2)	45	17.8	16.8	1.1	65.02
(6, 23)	1,111	334.8	238	96.7	48.88
(7, 5)	420	228.6	213.9	14.6	64.55
(13, 6)	0	57.6	42.5	15.1	25.65
(15, 26)	714	206	135.7	70.3	44.34
(22, 7)	22	6.8	6.3	0.4	60.73
(23, 15)	32	17.3	6.8	10.5	27.52
(24, 2)	0	45.8	42.4	3.4	32.27
(25, 22)	449	149.9	136.1	13.8	62.77
(26, 87)	21	7.5	4.9	2.6	45.32
(31, 87)	0	3.4	3.3	0.2	33.2
(32, 25)	33	7.8	6.9	0.9	61.45
(41, 32)	642	291.8	258.8	32.9	61.3
(42, 41)	0	3.6	3.5	0.1	36.57
(43, 41)	35	6.6	4.9	1.7	51.67
(44, 46)	24	9.1	6.9	2.3	52.3
(46, 48)	539	145.2	129.2	16.1	61.57
(47, 43)	650	198.7	148.3	50.3	51.51
(48, 50)	40	6.5	5.9	0.6	62.68
(49, 47)	20	12.6	5.9	6.7	32.52
(50, 52)	591	141.8	129.2	12.6	63.08
(51, 49)	653	190.2	131	59.2	47.59
(52, 54)	47	7.4	5.9	1.5	55.23
(53, 51)	41	14.3	5.8	8.5	28.68
(54, 76)	623	287.3	259.2	28.1	62.25
(63, 46)	0	1	1	0	34.56
(65, 50)	0	3.1	3	0.1	33.2
(66, 47)	0	3.2	2.9	0.2	32.22
(71, 54)	0	3.6	3.4	0.2	33.09
(72, 51)	0	3.3	3	0.4	31.01
(73, 75)	24	6.3	5.7	0.6	63.75
(74, 84)	274	16.8	11.8	5	48.42
(75, 53)	1,038	253	209.6	43.4	58.19
(76, 74)	110	7.1	5.9	1.1	57.88
(81, 75)	0	3	2.9	0.1	33.84
(82, 74)	0	2.9	2.7	0.2	32.05
(83, 73)	162	13.4	11.9	1.5	62.36
(85, 7)	0	2.7	1.8	0.9	42.56
(86, 15)	0	4	1.8	2.2	28.8

TABLE F.7: CORSIM Output for Scenario 4 Involving Restricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	300	140.4	124.8	15.6	62.15
(3, 4)	211	175.8	124.6	51.2	49.63
(4, 6)	27	55.8	16.5	39.3	20.76
(5, 2)	48	18.8	16.4	2.4	61.56
(6, 23)	362	352.1	241.7	110.4	46.47
(7, 5)	356	241.2	210.4	30.8	61.18
(13, 6)	0	68.6	42.1	26.5	21.55
(15, 26)	369	205.7	136.7	69	44.41
(22, 7)	31	8.2	6.3	1.9	50.04
(23, 15)	11	22.9	6.8	16.1	20.85
(24, 2)	0	45.9	42.7	3.2	32.18
(25, 22)	348	157.6	134.6	23	59.7
(26, 87)	35	11.6	4.9	6.7	29.48
(31, 87)	0	4.4	3.2	1.2	26.04
(32, 25)	31	11	6.9	4.1	43.68
(41, 32)	292	313.1	258.2	54.9	57.12
(42, 41)	0	4.3	3.6	0.7	30.93
(43, 41)	18	11.9	4.9	7	28.75
(44, 46)	41	9.7	6.8	2.8	49.34
(46, 48)	402	151.2	128	23.2	59.15
(47, 43)	320	204.2	148.8	55.4	50.1
(48, 50)	49	10.7	5.8	4.9	38.14
(49, 47)	24	15.4	5.9	9.6	26.56
(50, 52)	491	166.2	129.2	37	53.8
(51, 49)	345	196.6	133	63.6	46.05
(52, 54)	51	11.7	5.8	5.9	34.98
(53, 51)	25	19.1	5.9	13.2	21.42
(54, 76)	462	301.5	257.2	44.3	59.32
(63, 46)	0	1	0.9	0	34.36
(65, 50)	0	3.7	2.9	0.7	28.26
(66, 47)	0	3.8	2.9	0.9	26.93
(71, 54)	0	4.2	3.4	0.9	27.96
(72, 51)	0	4.3	2.9	1.4	23.68
(73, 75)	7	18.7	5.7	12.9	21.63
(74, 84)	270	20.6	11.7	8.8	39.43
(75, 53)	394	316.1	215	101.1	46.57
(76, 74)	118	9.1	5.9	3.3	44.82
(81, 75)	0	5.3	2.9	2.4	19.25
(82, 74)	0	3	2.6	0.4	30.61
(83, 73)	225	34.3	11.9	22.4	24.35
(85, 7)	0	2.8	1.7	1.1	40.39
(86, 15)	0	5.4	1.7	3.6	21.23

TABLE F.8: CORSIM Output for Scenario 4 Involving Unrestricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	305	141.2	125.2	16	61.81
(3, 4)	74	160.2	124.2	36	54.49
(4, 6)	16	63.7	16.5	47.2	18.19
(5, 2)	48	19.4	16.5	2.9	59.63
(6, 23)	331	375.4	244.6	130.8	43.59
(7, 5)	321	242.5	210.9	31.6	60.84
(13, 6)	0	72.1	41.9	30.1	20.5
(15, 26)	369	206.4	135.2	71.2	44.26
(22, 7)	28	8.8	6.3	2.5	46.49
(23, 15)	17	22.2	6.8	15.5	21.46
(24, 2)	0	45.7	42.7	3	32.34
(25, 22)	322	157.9	134.5	23.4	59.58
(26, 87)	39	11.4	4.8	6.6	29.85
(31, 87)	0	4.3	3.2	1.1	26.49
(32, 25)	40	9.8	6.9	2.9	49.21
(41, 32)	311	313.6	258.1	55.5	57.03
(42, 41)	0	4.2	3.6	0.6	31.21
(43, 41)	25	12	4.9	7.1	28.45
(44, 46)	54	10.2	6.8	3.3	46.96
(46, 48)	406	151.5	128	23.5	59.02
(47, 43)	315	210.3	149.8	60.5	48.65
(48, 50)	52	9.2	5.8	3.3	44.59
(49, 47)	20	17.3	5.9	11.4	23.68
(50, 52)	454	167.6	129	38.6	53.34
(51, 49)	326	194.5	131.9	62.6	46.54
(52, 54)	44	14.1	5.9	8.2	29.01
(53, 51)	16	18.7	5.8	12.9	21.85
(54, 76)	423	304.5	258.6	45.9	58.73
(63, 46)	0	1	0.9	0.1	34.05
(65, 50)	0	3.5	2.9	0.6	29.58
(66, 47)	0	4	2.9	1.1	25.33
(71, 54)	0	4.5	3.4	1.2	26.26
(72, 51)	0	4.1	2.9	1.2	24.9
(73, 75)	4	17.6	5.7	11.9	22.89
(74, 84)	250	23	11.9	11.2	35.24
(75, 53)	319	332.1	216.4	115.7	44.34
(76, 74)	141	8.6	5.9	2.7	47.61
(81, 75)	0	5.3	2.9	2.4	19.08
(82, 74)	0	3.1	2.6	0.5	29.41
(83, 73)	174	31.5	11.9	19.5	26.53
(85, 7)	0	2.8	1.7	1.1	39.99
(86, 15)	0	5.2	1.7	3.4	22.03

TABLE F.9: CORSIM Output for Scenario 5 Involving Restricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (Sec/veh)	Speed (mph)
(2, 1)	529	129.5	125.4	4.1	67.4
(3, 4)	475	128.7	124.2	4.5	67.82
(4, 6)	53	17.4	16.5	0.9	66.8
(5, 2)	33	17	16.6	0.3	68.38
(6, 23)	2,498	251.3	232.9	18.4	65.12
(7, 5)	785	217.3	212.2	5.1	67.9
(13, 6)	0	46.6	42.1	4.5	31.7
(15, 26)	1,247	141	130.2	10.8	64.77
(22, 7)	13	6.4	6.3	0.1	64.14
(23, 15)	32	7.2	6.8	0.4	66.03
(24, 2)	0	46	42.4	3.6	32.1
(25, 22)	726	140.3	135.3	5	67.05
(26, 87)	36	5.2	4.9	0.3	65.47
(31, 87)	0	3.3	3.3	0	34.55
(32, 25)	14	7.2	6.9	0.3	66.98
(41, 32)	1,235	272.2	257.5	14.7	65.7
(42, 41)	0	3.5	3.4	0	38.09
(43, 41)	13	5.1	4.9	0.2	66.3
(44, 46)	11	7.1	6.8	0.3	67.02
(46, 48)	745	134.8	128.1	6.7	66.33
(47, 43)	915	155.3	146.9	8.4	65.89
(48, 50)	13	6	5.9	0.2	68.03
(49, 47)	18	6.2	5.9	0.3	66.27
(50, 52)	813	132.9	128.4	4.5	67.29
(51, 49)	896	136.7	129.6	7.1	66.23
(52, 54)	15	6	5.9	0.1	68.19
(53, 51)	53	6.1	5.8	0.3	66.97
(54, 76)	1,246	265.5	257.8	7.8	67.35
(63, 46)	0	1	1	0	35.28
(65, 50)	0	3	3	0	34.62
(66, 47)	0	2.9	2.9	0	34.68
(71, 54)	0	3.4	3.4	0	34.48
(72, 51)	0	3	2.9	0	34.6
(73, 75)	11	5.9	5.7	0.2	68.49
(74, 84)	287	13.6	11.7	1.9	59.72
(75, 53)	1,390	219.7	210.4	9.3	67.03
(76, 74)	38	6.2	5.9	0.3	65.49
(81, 75)	0	2.9	2.9	0	34.76
(82, 74)	0	2.7	2.6	0	34.37
(83, 73)	165	12.3	11.9	0.4	67.71
(85, 7)	0	2.7	1.8	0.9	42.75
(86, 15)	0	2.7	1.8	0.9	42.91

TABLE F.10: CORSIM Output for Scenario 5 Involving Unrestricted Operations During the Daytime

Link	Lane change	Total time (sec/veh)	Move time (sec/veh)	Delay time (sec/veh)	Speed (mph)
(2, 1)	546	129.3	125.4	3.9	67.51
(3, 4)	595	128.3	124.3	4.1	68.01
(4, 6)	55	17.1	16.5	0.6	67.66
(5, 2)	28	16.9	16.6	0.2	68.67
(6, 23)	2,827	250.3	232.7	17.6	65.38
(7, 5)	861	216.7	212	4.7	68.08
(13, 6)	0	46.6	42.1	4.4	31.72
(15, 26)	1,351	139.6	130.3	9.3	65.41
(22, 7)	6	6.4	6.3	0.1	64.05
(23, 15)	44	7.3	6.8	0.5	65.5
(24, 2)	0	45.5	42.5	3	32.48
(25, 22)	717	141.2	135.1	6.1	66.65
(26, 87)	25	5.1	4.9	0.3	66.25
(31, 87)	0	3.3	3.3	0	34.55
(32, 25)	22	7.2	6.9	0.3	66.43
(41, 32)	1,510	270.8	256.3	14.5	66.05
(42, 41)	0	3.5	3.4	0	38.08
(43, 41)	14	5.1	4.9	0.2	66.71
(44, 46)	20	7.2	6.8	0.3	66.74
(46, 48)	775	134.1	128.1	6	66.68
(47, 43)	1,046	154.1	146.3	7.8	66.39
(48, 50)	9	6	5.8	0.2	67.92
(49, 47)	38	6.1	5.8	0.3	66.89
(50, 52)	833	133.4	128.4	5	67.04
(51, 49)	1,060	135.9	129.1	6.8	66.62
(52, 54)	20	6	5.9	0.2	67.85
(53, 51)	32	6.1	5.8	0.2	67.5
(54, 76)	1,218	264.3	257.4	6.9	67.66
(63, 46)	0	1	1	0	35.32
(65, 50)	0	3	3	0	34.59
(66, 47)	0	2.9	2.9	0	34.72
(71, 54)	0	3.4	3.4	0	34.46
(72, 51)	0	3	2.9	0	34.59
(73, 75)	8	5.8	5.7	0.1	69.03
(74, 84)	267	13.3	11.7	1.6	61.05
(75, 53)	1,419	218.6	209.2	9.4	67.35
(76, 74)	14	6	5.9	0.1	67.66
(81, 75)	0	2.9	2.9	0	34.76
(82, 74)	0	2.7	2.6	0	34.38
(83, 73)	151	12.3	11.8	0.4	68.06
(85, 7)	0	2.7	1.8	0.9	42.77
(86, 15)	0	2.7	1.8	0.9	42.9

APPENDIX G

CRASH SUMMARIES

TABLE G.1: Crash Summary by Month of Occurrence

Crash Conditions				
Roadway Conditions	**1999**	**2000**	**Total**	**Percent**
Dry	124	136	260	61.0
Wet	91	73	164	38.5
Slippery	2	0	2	0.5
Other	0	0	0	0.0
Total	217	209	426	100.0
Lighting Conditions	**1999**	**2000**	**Total**	**Percent**
Daylight	114	142	256	60.3
Dark (Night)	92	61	153	35.7
Dusk/Dawn	11	6	17	4.0
Total	217	209	426	100.0
Weather Conditions	**1999**	**2000**	**Total**	**Percent**
Clear	109	123	232	54.5
Cloudy	38	29	67	15.7
Rain	69	55	124	29.1
Fog	1	2	3	0.7
Total	217	209	426	100.0

Crash Occurrence By Month				
	1999	**2000**	**Total**	**Percent**
January	26	14	40	9.4
February	12	15	27	6.3
March	18	12	30	7.0
April	13	21	34	8.0
May	25	15	40	9.4
June	19	20	39	9.2
July	22	16	38	8.9
August	9	17	26	6.1
September	19	12	31	7.3
October	11	22	33	7.8
November	27	23	50	11.7
December	16	22	38	8.9
Total	217	209	426	100.0

TABLE G.2: Crash Summary by Severity and Crash Type

Crash severity				
Severity	**1999**	**2000**	**Total**	**Percent**
PDO	101	110	211	49.5
Injury	96	85	181	42.5
Fatal Injury	5	5	10	2.4
Non-Reportable	15	9	24	5.6
Total	217	209	426	100.0
Crash Types				
	1999	**2000**	**Total**	**Percent**
Ran Off Roadway	67	24	91	21.4
Rear end	59	49	108	25.4
Sideswipe	35	37	72	16.9
Angle	18	10	28	6.6
Fixed Object	32	79	111	26.0
Head On	0	2	2	0.5
Pedestrian	0	1	1	0.2
Parked Vehicle	3	1	4	0.9
Other	3	6	9	2.1
Total	217	209	426	100.0
Crashes By vehicle Types				
	1999	**2000**	**Total**	**Percent**
Trucks	50	38	88	20.7
Passenger cars	167	171	338	79.3
Total	217	209	426	100.0
Crashes Involving Trucks By Time-Of-The-Day				
	1999	**2000**	**Total**	**Percent**
Day	26	18	44	50.0
Night	24	20	44	50.0
Total	50	38	88	100.0
Crashes Where Trucks Were at Fault By Time-Of-The-Day				
	1999	**2000**	**Total**	**Percent**
Day	16	15	31	53.4
Night	13	14	27	46.6
Total	29	29	58	100.0

TABLE G.3: Crash Summary by Vehicle Movement and Violation Behavior

Direction Of Travel and Vehicle Movement

Direction Of Travel	**1999**	**2000**	**Total**	**Percent**
North	172	210	382	53.4
South	179	150	329	46.0
Not Stated	3	1	4	0.6
Total	354	361	715	100.0

Vehicle Movement	**1999**	**2000**	**Total**	**Percent**
Straight ahead	215	231	446	62.4
Slowing/stopped	7	4	11	1.5
Backing	1	0	1	0.1
Changing lanes	112	103	215	30.1
Properly Parked	3	1	4	0.6
Other	16	22	38	5.3
Total	354	361	715	100.0

Vehicle Exceeded Posted Speed By

	1999			
UP TO 10 MPH	62			
UP TO 20 MPH	26			
UP TO 30 MPH	12			
UP TO 40 MPH	8			
UP TO 50 MPH	4			
OVER 50 MPH	3			

Driver's Violation Behavior

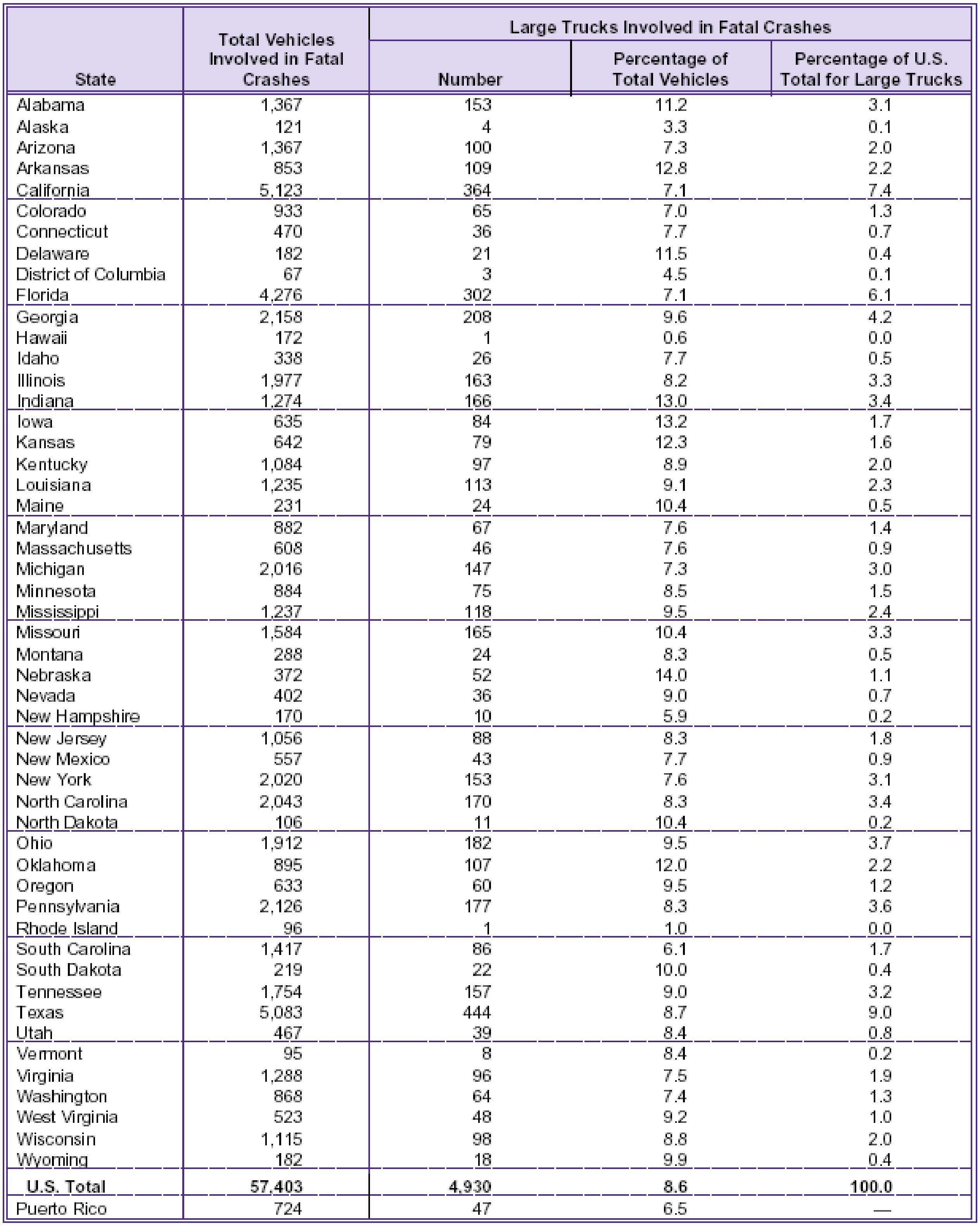
	1999	**2000**	**Total**	**Percent**
Reckless Driving	2	3	5	0.7
Careless driving	58	112	170	23.8
Improper lane Change	98	103	201	28.1
Exceeded State Speed Limit	115	69	184	25.7
Exceeded Safe Speed Limit	31	24	55	7.7
Speed Too Fast For Conditions	10	19	29	4.0
Improper Passing	8	13	21	2.9
Obstructing Traffic	23	11	34	4.8
Impaired(Alcohol/Drugs)	0	4	4	0.6
Other	9	3	12	1.7
Total	354	361	715	100.0

TABLE G.4: Crash Summary by Time of the Day

Occurrence by Hour of Day and Day of Week

Hour/Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total	Percent
00:00 - 00:59	1	1	1	2	1	3		9	2.1
01:00 - 01:59		2	1	2	3	4	1	13	3.1
02:00 - 02:59	1			1	4	1	1	8	1.9
03:00 - 03:59		2	3	1	1	1	1	9	2.1
04:00 - 04:59	2	2	3			3	1	11	2.6
05:00 - 05:59	2		1	2	1	2	1	9	2.1
06:00 - 06:59	1	2	1		1	3		8	1.9
07:00 - 07:59	2	2	3	1	3			11	2.6
08:00 - 08:59	3	1	1	3		4	5	17	4.0
09:00 - 09:59	1			4	5	2	1	13	3.1
10:00 - 10:59	2	2		1	6	2	3	16	3.8
11:00 - 11:59	4	1	3	3	5	5	1	22	5.2
12:00 - 12:59	5	2		3	6	4	5	25	5.9
13:00 - 13:59	6	1	4	3	3	4	2	23	5.4
14:00 - 14:59	5	1	3	4	8	1	3	25	5.9
15:00 - 15:59	1	2	1	3	4	4	2	17	4.0
16:00 - 16:59	4	2	6		8	5	2	27	6.3
17:00 - 17:59	4	4	7	6	3	6	7	37	8.7
18:00 - 18:59	1	2	6	3	6	5	3	26	6.1
19:00 - 19:59	1	1	6	6	1	2	4	21	4.9
20:00 - 20:59	3	2	2	3	4	3	3	20	4.7
21:00 - 21:59	3	3	1	3	2	3	4	19	4.5
22:00 - 22:59	4	2	3	3	6	4	3	25	5.9
23:00 - 23:59			2	2	5	2	4	15	3.5
Total	56	37	58	59	86	73	57	426	100.0
Percent	13.1	8.7	13.6	13.8	20.2	17.1	13.4	100.0	

TABLE G.5: Year 2000 Large Trucks Involvement in Fatal Crashes by State



State	Total Vehicles Involved in Fatal Crashes	Large Trucks Involved in Fatal Crashes		
		Number	Percentage of Total Vehicles	Percentage of U.S. Total for Large Trucks
Alabama	1,367	153	11.2	3.1
Alaska	121	4	3.3	0.1
Arizona	1,367	100	7.3	2.0
Arkansas	853	109	12.8	2.2
California	5,123	364	7.1	7.4
Colorado	933	65	7.0	1.3
Connecticut	470	36	7.7	0.7
Delaware	182	21	11.5	0.4
District of Columbia	67	3	4.5	0.1
Florida	4,276	302	7.1	6.1
Georgia	2,158	208	9.6	4.2
Hawaii	172	1	0.6	0.0
Idaho	338	26	7.7	0.5
Illinois	1,977	163	8.2	3.3
Indiana	1,274	166	13.0	3.4
Iowa	635	84	13.2	1.7
Kansas	642	79	12.3	1.6
Kentucky	1,084	97	8.9	2.0
Louisiana	1,235	113	9.1	2.3
Maine	231	24	10.4	0.5
Maryland	882	67	7.6	1.4
Massachusetts	608	46	7.6	0.9
Michigan	2,016	147	7.3	3.0
Minnesota	884	75	8.5	1.5
Mississippi	1,237	118	9.5	2.4
Missouri	1,584	165	10.4	3.3
Montana	288	24	8.3	0.5
Nebraska	372	52	14.0	1.1
Nevada	402	36	9.0	0.7
New Hampshire	170	10	5.9	0.2
New Jersey	1,056	88	8.3	1.8
New Mexico	557	43	7.7	0.9
New York	2,020	153	7.6	3.1
North Carolina	2,043	170	8.3	3.4
North Dakota	106	11	10.4	0.2
Ohio	1,912	182	9.5	3.7
Oklahoma	895	107	12.0	2.2
Oregon	633	60	9.5	1.2
Pennsylvania	2,126	177	8.3	3.6
Rhode Island	96	1	1.0	0.0
South Carolina	1,417	86	6.1	1.7
South Dakota	219	22	10.0	0.4
Tennessee	1,754	157	9.0	3.2
Texas	5,083	444	8.7	9.0
Utah	467	39	8.4	0.8
Vermont	95	8	8.4	0.2
Virginia	1,288	96	7.5	1.9
Washington	868	64	7.4	1.3
West Virginia	523	48	9.2	1.0
Wisconsin	1,115	98	8.8	2.0
Wyoming	182	18	9.9	0.4
U.S. Total	**57,403**	**4,930**	**8.6**	**100.0**
Puerto Rico	724	47	6.5	—